DESIGN SPECIFICATIONS FOR MEMBRANE KEYBOARDS

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Contents

Micro-Motion Flat Membrane Keyboard

1.1 Micro-Motion Flat Membrane Keyboard

The micro-motion flat membrane keyboard is the standard non-tactile keyboard and consists of the following components:

- A flexible upper circuit layer
- A flexible or rigid (PCB) lower circuit layer
- An insulating spacer layer
- A graphic overlay

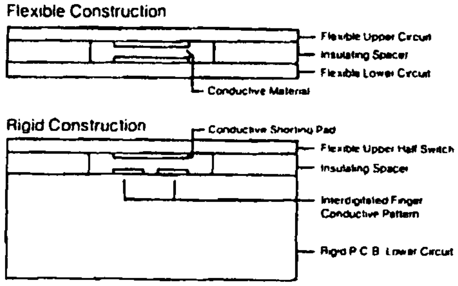
The upper circuit layer is flexible polyester film and the lower circuit can either be flexible or rigid (PCB). The two circuit layers are separated by an insulating spacer layer with openings cut at key locations. Pressure applied to a key location flexes the upper circuit through the spacer opening bringing it in contact with a lower circuit, producing a momentary switch closure.

The following illustrations show the positioning of the various components and highlight the differences between flexible and rigid construction:

Micro-Motion/Flat Membrane

Single Key Cross-Section

Flexible Construction

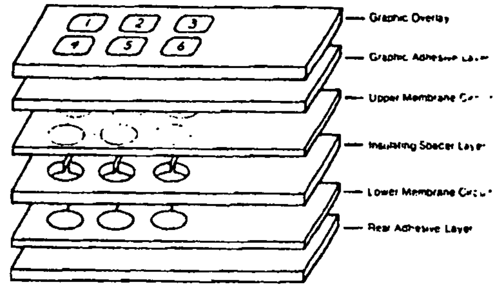


1.1.1 Materials and Bonding

The standard circuit and spacer substrate consists of polyester material. The circuit is typically a screen-printed silver ink composition. A printed circuit board with plated contacts can be used as the lower circuit layer to form a rigid backer and facilitate electronic component assembly. Alternate contact materials include carbon or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel, or nickel/gold plate in the case of a rigid lower PCB circuit.

A graphic overlay mounted to the top of the upper circuit designates key locations. The overlay usually is either polyester or polycarbonate material.

Micro-Motion Flat Membrane



It is strongly recommended that all keyboards be environmentally sealed with laminate acrylic adhesives. However, manufacturing costs can be lowered by using ultrasonic welding or heat staking to secure the switch layers

1.1.2 Contact Materials

Contact materials include silver, carbon, or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel, or nickel/gold plate in the case of a rigid lower PCB circuit.

1.1.3 Standard Switch Travel

Standard switch travel is .008". However, travel varies according to spacer thickness. Minimum switch travel is .005".

Note

Switch travel is defined as the distance travelled by the upper circuit from its resting position to the point of contact with the lower circuit.

1.1.4 Standard Thickness

Typical thickness for a flexible switch with a graphic overlay is .044". If a .062" rigid PCB lower circuit is used, then standard thickness is .093".

The following considerations affect the total thickness of the keyboard:

- The type of lower circuit and the rear adhesive mounting system.
- The thickness of the spacer layer which determines switch travel.
- Adhesive-sealed keyboards with a graphic overlay are typically .005" thicker. This additional thickness is due to the adhesive itself.

Actual keyboard thickness varies depending on customer specifications and requirements.

1.1.5 Actuation Force

Actuation force of a micro-motion flat membrane keyboard is typically specified between 4 and 8 ounces, allowing for a tolerance of ± 2 ounces. Keep in mind that tight tolerance and/or low actuation forces can be achieved, but require hard tooling and design modifications.

The actuation force required to operate a switch is a function of the diameter of the switch opening cut in the spacer between the upper and lower circuits and the spacer layer thickness.

1.1.6 Standard Tooling and Tolerance
The micro-motion flat membrane keyboard is typically tooled using steel rule dies. This method results in dimensional tolerances of ± .010" To achieve dimensional tolerances of ± .005" more expensive male/female hard tooling must be employed

1.1.7 Operating and Storage Temperature
Operating and storage temperature ranges from −40°C to 85°C.

1.1.8 Contact Bounce
Contact bounce for a flexible membrane is typically 5 milliseconds or less. A rigid lower PCB improves contact bounce time In addition, contact materials such as gold plate further reduce contact bounce.

1.1.9 Encoding
In most cases. the following circuit layouts can be used:

- x/y
- Common buss
- 2 pole
- 3 pole
- 4 pole

1.1.10 Electrical
The maximum circuit rating is 30V DC, 100 milliamps, 1 watt.

1.1.11 Life Expectancy
Micro-motion flat membrane keyboards will meet or exceed ten million closures.

Tactile Membrane Keyboard/Plastic

1.2 Tactile Membrane Keyboard
The tactile membrane keyboard resembles the micro-motion flat membrane construction except that the upper circuit is domed. The tactile membrane keyboard consists of the following components:

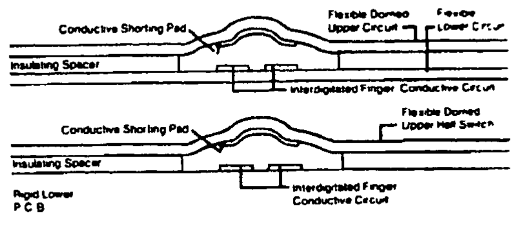
- A domed upper circuit layer
- A flexible or rigid (PCB) lower circuit layer
- An insulating spacer layer
- A graphic overlay

Pressure applied to the raised key location causes the protrusion in the upper circuit to flex through the spacer opening. This action results in a momentary switch closure and simultaneous tactile feedback.

The following figures show the positioning of the various components of the tactile membrane keyboard and highlight the differences between flexible and rigid construction:

Tactile/Membrane/Plastic

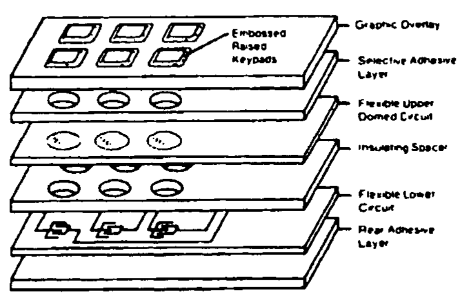
Single Key Cross-Section



1.2.1 Materials and Bonding
The standard circuit and spacer substrate consists of polyester material. The circuit is typically a screen-printed silver ink composition. A printed circuit board with plated contacts can be used as the lower circuit layer to form a rigid backer and facilitate electronic component assembly. Alternate contact materials include carbon or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel, or nickel/gold plate in the case of a rigid lower PCB circuit.

A graphic overlay mounted to the top of the upper circuit is embossed at key locations. The overlay usually is either polyester or polycarbonate material.

Tactile Membrane Keyboard Assembly



It is strongly recommended that tactile membrane keyboards be environmentally sealed with laminate acrylic adhesives. However, manufacturing costs can be lowered by using ultrasonic welding or heat staking to secure the switch layers.

1.2.2 Contact Materials
Contact materials include silver, carbon, or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel, or nickel/gold plate in the case of a rigid lower PCB circuit.

1.2.3 Standard Switch Travel
Maximum switch travel is .032" and minimum travel is .020", dome height ranges from .017" to .033" depending on the actuation force and travel requirements. Typical dome height is .025".

1.2.4 Standard Thickness
Typical thickness for a flexible switch with a graphic overlay is .056". If a rigid PCB lower circuit is used, then standard thickness is .105".

1.2.5 Actuation Force
Actuation force of this switch is typically 8 to 12 ounces, allowing for a tolerance of ±2 ounces.

Actuation forces significantly under 8 ounces sacrifice the snap action. Travel remains unaffected, however, producing a softer feel.

1.2.6 Standard Tooling and Tolerance
The tactile membrane keyboard is typically tooled using steel rule dies. This method results in dimensional tolerances of ±.010". To achieve dimensional tolerances of ±.005", a more expensive male/female hard tooling must be employed.

In addition, upper circuit doming requires match mold sets which increase tooling costs. Moreover, when a graphic overlay is included, an embossing tool must be used to raise the keypad on the graphics. This procedure ensures that no preload is placed on the dome.

1.2.7 Operating and Storage Temperature
Operating and storage temperature ranges from −40°C to 85°C.

1.2.8 Contact Bounce
Contact bounce is typically 5 milliseconds or less. A rigid lower PCB with optional gold contacts reduces contact bounce time.

1.2.9 Encoding
In most cases, the following circuit layouts can be used:

- x/y
- Common buss
- 2 pole
- 3 pole
- 4 pole

Note
Three and four pole switches have limitations with respect to contact bounce and density of layout. They typically require a specially shaped, injection-molded actuator.

1.2.10 Electrical
The maximum circuit rating is 30V DC, 100 milliamps, 1 watt.

1.2.11 Life Expectancy
Tactile membrane keyboards meet or exceed three million closures.

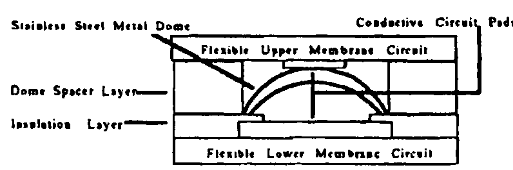
Metal Dome Membrane Keyboard

1.3 Metal Dome Membrane Keyboard

In a metal dome membrane keyboard the domes are placed on a dielectric insulating layer which has been applied to the outer perimeter of the contact on the lower membrane circuit. The dome is secured in position by the dome spacer layer. The upper membrane circuit is positioned over the dome with the conductive material of the upper circuit making contact to the dome. Pressure applied to the dome allows it travel through the dome spacer layer and make contact to the lower circuit creating a momentary switch closure. This action also produces a tactile response. (Refer to Section 6.8 for information on metal dome specifics)

The following figure shows the positioning of the various components of the metal dome membrane keyboard:

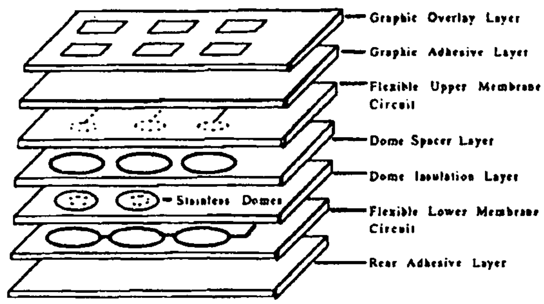
Tactile Metal Dome Flexible Membrane Switch
Single Key Cross-Section



1.3.1 Materials and Bonding
The standard upper and lower circuits and spacer substrate consist of polyester material while the metal domes are made of stainless steel. The circuit is typically a screen-printed silver ink composition. A printed circuit board with plated contacts can be used as the lower circuit layer to form a rigid backer and facilitate electronic component assembly. Alternate contact materials include carbon or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel, or nickel/gold plate in the case of a rigid lower PCB circuit.

A graphic overlay mounted to the top of the upper circuit may be embossed at key locations. The overlay usually consists of either polyester or polycarbonate.

Tactile Metal Dome Over Flexible Membrane Switch



It is strongly recommended that all keyboards be environmentally sealed with laminate acrylic adhesives. Lower cost unsealed assemblies use ultrasonic welding or heat staking.

1.3.2 Contact Materials
Contact materials include silver, carbon, or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel, or nickel/gold plate in the case of a rigid lower PCB circuit.

1.3.3 Standard Switch Travel
Switch travel is typically .020".

1.3.4 Standard Thickness
Thickness varies between .053" and .081", depending on customer requirements.

1.3.5 Actuation Force
Actuation force of this switch is typically 10 to 14 ounces, allowing for a variation rate of ±2 ounces.

Actuation forces significantly under 8 ounces lose their snap action. Travel remains unaffected, however, producing a softer feel.

Note:
Extreme temperatures result in variation in the feel of the keyboard

1.3.6 Standard Tooling and Tolerance
The metal dome membrane keyboard is tooled using steel rule dies. This method results in dimensional tolerances of ±.010". To achieve dimensional tolerances of ±.005", a more expensive male/female hard tooling must be employed.

Moreover, when a graphic overlay is included, an embossing tool must be used to raise the keypad on the graphics.

1.3.7 Operating and Storage Temperature
Operating and storage temperature ranges from −40°C to 85°C.

1.3.8 Contact Bounce
Metal dome keyboards have a contact bounce of less than 5 milliseconds. Optimum results are achieved by using gold contacts, which in turn reduce contact bounce time. Minimum contact bounce is 1 millisecond.

1.3.9 Encoding
In most cases, the following circuit layouts can be used:

- x/y
- Common buss
- 2 pole

1.3.10 Electrical
The maximum circuit rating is 30V DC, 100 milliamps, 1 watt.

1.3.11 Life Expectancy
Metal dome membrane keyboards meet or exceed three million closures.

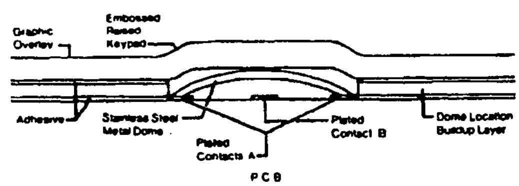
Tactile Metal Dome/PCB Keyboard

1.4 Tactile Metal Dome/PCB Keyboard
A tactile metal dome/PCB keyboard uses snap-action metal domes over contacts on a printed circuit board. When pressure is applied to a key location, the dome flexes and shorts the outer and inner PCB contacts. This action simultaneously produces a momentary switch closure and tactile feedback.

The following figure shows the positioning of the various components of the tactile metal dome/PCB keyboard:

Tactile Metal Dome/P.C.B.

Single Key Cross-Section



1.4.1 Materials and Bonding
A printed circuit board with plated contacts serves as the lower circuit layer. The standard PCB thickness is .062", but .032" and .092" can also be used.

The printed circuit board's contact material is typically tin/lead reflow over copper. Nickel and nickel/gold are available as options. The upper contact consists of the snappable stainless steel dome, which can be gold plated if desired.

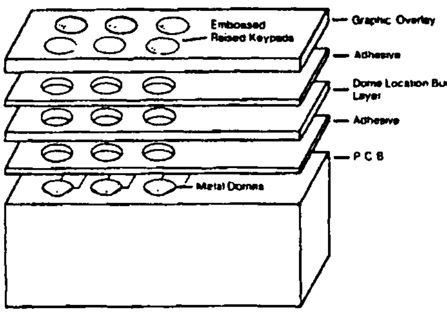
The domes are held in position in one of two ways:

1 Placed within die-cut openings in a locator layer that is adhesive-bonded to the PCB.

2 Overlaminated with adhesive-backed polyester.

A graphic overlay mounted to the top of the upper circuit designates key locations. When a graphic overlay is either not used or removable, a thin film is laminated over the dome locator layer to prevent movement of the domes.

Tactile Metal Dome/P.C.B. Assembly



1.4.2 Contact Materials
Contact materials include silver, carbon, or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel, or nickel/gold plate in the case of a rigid lower PCB circuit with metal domes.

1.4.3 Standard Switch Travel
Switch travel is typically .025". Minimum travel is .020".

1.4.4 Standard Thickness
Standard thickness is typically .085".

1.4.5 Actuation Force
Actuation force of this switch is typically 12 to 16 ounces, allowing for a tolerance of 2 ounces.

Actuation forces significantly under 8 ounces lose their snap action. Travel remains unaffected, however, producing a softer feel.

1.4.6 Standard Tooling and Tolerance
The flexible layers of the metal dome/PCB keyboard are tooled using steel rule dies. This method results in dimensional tolerances of ± .010".

1.4.7 Operating and Storage Temperature
Operating and storage temperature ranges from −40°C to 85°C.

1.4.8 Contact Bounce
Metal dome keyboards have a typical contact bounce o' [illegible] than 5 milliseconds.

1.4.9 Encoding
In most cases, the following circuit layouts can be used

- x/y
- Common buss
- Two pole

1.4.10 Electrical
The maximum circuit rating is 30V DC, 100 milliamps, 1 wat

1.4.11 Life Expectancy
Metal Dome/PCB keyboards meet or exceed three million closures.

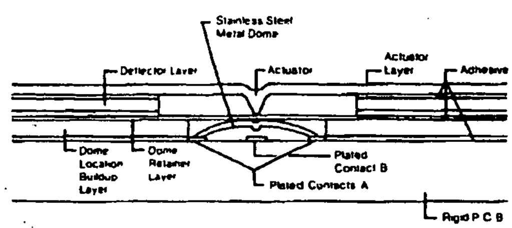
Tactile Metal Dome/PCB/Actuator Assembly

1.5 Tactile Metal Dome/PCB/Actuator Assembly
A tactile metal dome/PCB/actuator assembly adds an actuator layer to the keyboard described in Section 1.4. The actuator improves tactile feedback by centralizing pressure above a central depression on the metal dome.

The actuator layer has formed downward protrusions at key locations above the metal domes and is typically .010" thick These protrusions make contact with the depressions on the metal domes and result in improved feedback.

The following figure shows the positioning of the various components of the assembly:

Tactile Metal Dome/P.C B. with Actuator
Single Key Cross-Section

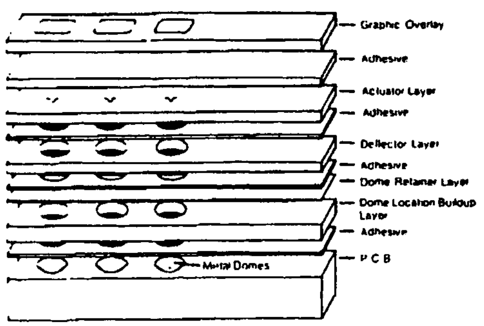


1.5.1 Materials and Bonding
The construction of this assembly resembles the metal dome/PCB keyboard.

In addition, a deflector layer is required below the formed polycarbonate actuator layer. This deflection layer provides the additional space required by the formed protrusion on the actuation layer. A dome location/buildup layer is placed beneath the deflector layer which correctly positions each metal dome on the PCB lower circuit.

The printed circuit board's contact material is typically tin/lead reflow over copper. Nickel and nickel/gold are available as options. The upper contact consists of the snappable stainless steel dome which can be gold plated if desired.

Tactile Metal Dome P C B with Actuator Assembly



Note
The graphic overlay need not be embossed in this type of construction.

1.5.2 Contact Materials
Contact materials include silver, carbon, or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel, or nickel/gold plate in the case of a rigid lower PCB circuit with metal domes.

1.5.3 Standard Switch Travel
Switch travel is typically .025". Minimum travel is .020".

1.5.4 Standard Thickness
Standard thickness is typically .116". However, thickness can be varied according to customer requirements.

1.5.5 Actuation Force
Actuation force of this switch is typically 10 to 14 ounces, allowing for a variation rate of ±2 ounces.

Actuation forces significantly under 8 ounces lose their snap action. Travel remains unaffected, however, producing a softer feel.

Note:
Extreme temperatures result in variation in the feel of the keyboard.

1.5.6 Standard Tooling and Tolerance
The metal dome PCB/actuator assembly is tooled using steel rule dies. This method results in dimensional tolerances of ±.010".

More costly male/female hard tooling can be used to achieve tolerances of ±.005". However, .005" is unusual for this assembly.

1.5.7 Operating and Storage Temperature
Operating and storage temperature ranges from −40°C to 85°C.

1.5.8 Contact Bounce
Metal dome keyboards have a contact bounce of less than 5 milliseconds.

1.5.9 Encoding
In most cases, the following circuit layouts can be used:

- x/y
- Common buss
- Two pole

1.5.10 Electrical
The maximum circuit rating is 30V DC, 100 milliamps, 1 watt.

1.5.11 Life Expectancy
Metal dome/PCB/actuator keyboards meet or exceed three million closures.

Tactile Floating Key Assembly

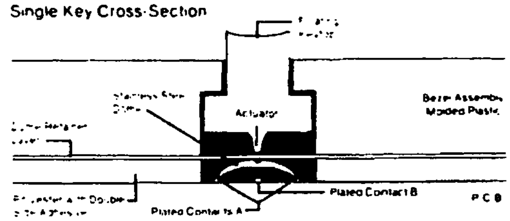
1.6 Tactile Floating Key Assembly
The tactile floating key assembly uses plastic keys in combination with either tactile membrane or metal dome switches. The keys are contained in a bezel or frame that is positioned over the switches.

The type of dome selected depends upon cost, life expectancy, and touch requirements.

The following figure shows one design of the tactile floating key assembly using a metal dome switch:

Tactile Floating Keytop

Single Key Cross-Section



1.6.1 Actuator
In either a tactile membrane or metal dome design, the actuator must be integral to the key itself. The polyester dome switch requires a round, flat actuator. In contrast, a metal dome must have a pointed actuator positioned over the depression in the dome's center.

1.6.2 Contact Materials
Contact materials include silver, carbon, or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel, or nickel/gold plate in the case of a rigid lower PCB circuit with metal domes.

1.6.3 Standard Switch Travel
Switch travel is typically .028" for a tactile membrane design and .025" for a metal dome design.

1.6.4 Standard Thickness
The thickness of the housing that holds the keys in position greatly influences the overall thickness of the assembly. In addition, thickness of a tactile membrane or metal dome switch assembly also depends on the type of lower circuit selected (flexible polyester or PCB), as well as the backer layer.

The standard thickness of a metal dome switch assembly without the the plastic frame is .087".

The standard thickness of a flexible polyester dome switch assembly without a backer is .053". (A typical backer thickness is .125".)

The standard thickness of a polyester dome switch assembly with a rigid PCB lower circuit is .105".

1.6.5 Actuation Force
Actuation force conforms to the standard for a polyester and metal dome switch assembly discussed in Sections 1.2 and 1.5. The characteristics of the floating keyboard make it much easier to vary the tactile feedback of the unit.

1.6.6 Standard Tooling and Tolerance
The tactile membrane and metal dome switch assemblies are tooled using steel rule dies. This method results in dimensional tolerances of ±.010".

More costly male/female hard tooling must be used to achieve dimensional tolerance of ±.005". In addition, the snap-action protrusions on polyester dome assemblies require match mold sets, increasing tooling costs.

1.6.7 Operating and Storage Temperature
Operating and storage temperature ranges from −40°C to 85°C.

Note
Extreme temperatures vary the actuation force and feel of the keyboard.

1.6.8 Contact Bounce
Contact bounce conforms to the standard for tactile membrane and metal dome switches as discussed in Sections 1.2 and 1.5.

1.6.9 Encoding
In most cases, the following circuit layouts can be used with tactile membrane dome switches:

- x/y
- Common buss
- 2 pole
- 3 pole
- 4 pole

Note
Three and four pole circuits often require a specially shaped actuator. In addition, they have limitations placed upon contact bounce and density of layout.

Metal dome switches can use the following circuit layouts:

- x/y
- Common buss
- 2 pole

1.6.10 Electrical
The maximum circuit rating is 30V DC, 100 milliamps, 1 watt

1.6.11 Life Expectancy
A tactile floating key assembly conforms to the standard for tactile membrane (3 million closures) and tactile metal dome (3 million closures).

Tactile Floating Actuator

1.7 Tactile Floating Actuator with Graphics Assembly
This assembly is either a metal dome or tactile membrane switch that has electronic components mounted between the graphic and circuit layers. A floating actuator transmits key actuation from the graphic overlay directly to the contact, thus bypassing the need for a second PCB to mount components.

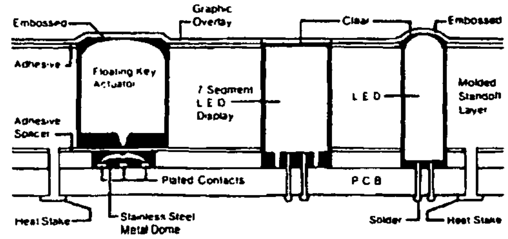
An injection-molded plastic frame provides a surface for the graphic overlay. The actuators are positioned within this frame and over each switch.

The thickness of the frame depends on the electronic components being used.

The following figure shows the design with display components mounted between the graphic and switch layers:

Tactile Floating Key Actuator/with Graphics

Single Key Cross-Section with LED Components Top Surface Mounted On P C B



1.7.1 Actuator Design
This assembly is usually used with metal dome, rather than polyester dome switches for cost consideration. High volume applications are better accommodated by using polyester domes in conjunction with a living hinge actuator. (See Section 1.9 for more detail.)

1.7.2 Contact Materials
Contact materials include silver, carbon, or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel, or nickel/gold plate in the case of a rigid lower PCB circuit with metal domes

1.7.3 Standard Switch Travel
Switch travel is typically .025" with metal domes and .028" when a tactile membrane design is used.

1.7.4 Standard Thickness
Keyboard thickness depends largely on the type of the actuators required and whether the keyboard is a tactile membrane or metal dome.

PCB thickness is usually .062" in these products.

Standard thickness for a metal dome keyboard without a plastic frame is .087".

Standard thickness for a polyester dome keyboard with a rigid PCB is .095".

1.7.5 Actuation Force
Actuation force is 12 ounces ±2 ounces for tactile membrane switches and 16 ounces ±2 ounces for metal dome switches. The characteristics of the floating keyboard make it much easier to vary the feel of the unit.

1.7.6 Standard Tooling and Tolerance
Metal dome and tactile membrane switch assemblies are tooled using steel rule dies. This method results in dimensional tolerances of ± .010".

More costly male/female hard tooling must be used to achieve dimensional tolerances of ± .005".

The domes on the tactile membrane switch require match mold sets, increasing tooling costs somewhat. Injection molding tooling is also necessary.

1.7.7 Operating and Storage Temperature
Operating and storage temperature ranges from −40°C to 85°C.

Note
Extreme temperatures cause the actuation force and feel of the keyboard to vary.

1.7.8 Contact Bounce
Contact bounce conforms to the standard for tactile membrane and metal dome keyboards. Refer to Sections 1.2 and 1.5.

1.7.9 Encoding
In most cases, the following circuit layouts can be used with polyester dome switches:

- x/y
- Common buss
- 2 pole
- 3 pole
- 4 pole

Note
Three and four pole circuits often require a specially shaped actuator. In addition, they have limitations placed upon contact bounce and density of layout.

Metal dome switches can use the following circuit layouts:

- x/y
- Common buss
- Two pole

1.7.10 Electrical
The maximum circuit rating is 30V DC, 100 milliamps, 1 watt.

1.7.11 Life Expectancy
A tactile floating key assembly conforms to the standard for tactile membrane (3 million closures) and tactile metal dome (3 million closures)

Tactile Living Hinge Key Assembly

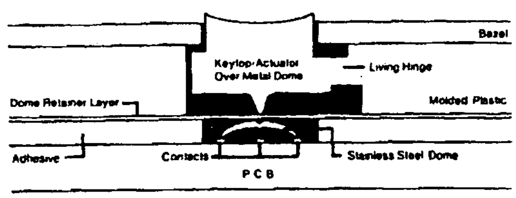
1.8 Tactile Living Hinge Key Assembly
This assembly resembles the floating key assembly described in Section 1.6. Either a tactile membrane or a metal dome switch may be used in conjunction with a frame to mount keys and actuators over the switches.

However, the key assembly is a single piece of plastic with tabs attaching the key to the frame. The tab is thinner at one point to act as a hinge, thus allowing the key to flex.

The primary advantage of a living hinge key design is that it reduces the number of parts and, consequently, assembly time.

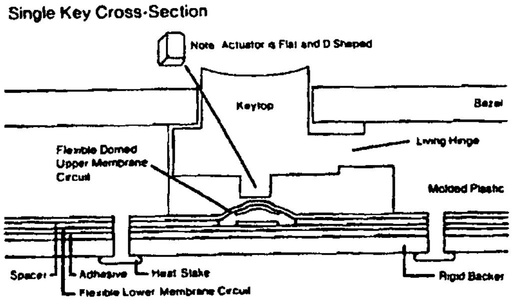
The following figures illustrate the actuator design of a living hinge keytop for use with either a tactile membrane or metal dome switch:

Tactile/Living Hinge Keytop



Keytop Actuator Over Tactile/Membrane

Single Key Cross-Section



Note
In certain applications the keyboard supplier may provide only the basic keyboard or the keyboard with the frame of keys.

1.8.1 Actuator Design
The actuator of the key used over a tactile membrane switch is D-shaped to ensure proper action. The actuator used over a metal dome, however, is pointed for proper positioning over the depression in the dome's center.

1.8.2 Contact Materials
Contact materials include silver, carbon, or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel or nickel/gold plate in the case of a rigid lower PCB circuit.

1.8.3 Standard Thickness
Naturally, the height of the keys and the thickness of the bezel influences the overall keyboard thickness. Typical thickness is .250".

1.8.4 Standard Switch Travel
Switch travel is typically .025" with a metal dome design and .028" with a tactile membrane design.

1.8.5 Actuation Force
Actuation force is 12 ounces ± 2 ounces for tactile membrane switches and 16 ounces ± 2 ounces for metal dome switches. The characteristics of the floating keyboard make it much easier to vary the feel of the unit.

1.8.6 Standard Tooling and Tolerance
The metal dome and tactile membrane switch assemblies are tooled using steel rule dies. This method results in dimensional tolerances of .010".

More costly male/female hard tooling must be used to achieve dimensional tolerance of ± .005". The snappable protrusions on polyester dome assemblies require match mold sets, increasing tooling costs. In addition, injection molding is required for key assembly.

1.8.7 Operating and Storage Temperature
Operating and storage temperature ranges from −40°C to 85°C.

Note
Extreme temperatures result in variation in the feel of the keyboard.

1.8.8 Contact Bounce
Contact bounce conforms to the standard for tactile membrane (Section 1.2) and metal dome keyboards (Section 1.5).

1.8.9 Encoding
In most cases, the following circuit layouts can be used with tactile membrane switches:

- x/y
- Common buss
- 2 pole
- 3 pole
- 4 pole

Note
Three and four pole circuits often require a specially shaped actuator. In addition, they have limitations placed upon contact bounce and density of layout.

The following circuit layouts can be used with metal dome switches:

- x/y
- Common buss
- 2 pole

1.8.10 Electrical
The maximum circuit rating is 30V DC, 100 milliamps, 1 watt.

1.8.11 Life Expectancy
A tactile floating key assembly conforms to the standard for tactile membrane (3 million closures) and tactile metal dome (3 million closures)

Living Hinge Actuator with Graphic Assembly

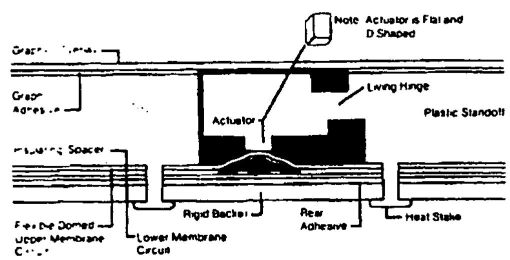
1.9 Living Hinge Actuator with Graphic Assembly
This assembly combines a tactile membrane switch assembly with a completely flat graphic overlay. Like the living hinge key assembly described in the previous section, this approach makes use of a frame assembly. However, this frame serves only as an actuator layer and does not have keytops. Instead the frame provides a mounting surface for a flat graphic overlay.

The molded actuator layer is typically heat staked to either a PCB lower circuit or a plastic backer (in the case of a flexible lower circuit).

It is not recommended that the living hinge with actuator and graphics be used with metal dome construction.

The following figure shows the design with a tactile membrane switch.

Tactile Living Hinge Actuator with Graphics



If desired, the actuator layer can be manufactured to allow electronic components to be mounted between the graphic and circuit layers. The advantages of this approach are discussed in Section 1.7.

1.9.1 Actuator Design
The actuator of the key used over a tactile membrane switch is D-shaped to ensure proper action.

1.9.2 Contact Materials
Contact materials include silver, carbon, or a silver/carbon blend when a flexible membrane is used and tin/lead, nickel, or nickel/gold plate in the case of a rigid lower PCB circuit.

1.9.3 Standard Thickness
Naturally, the thickness of the frame assembly influences the overall keyboard thickness. In addition, the type of lower circuit selected and the backer affect thickness.

A flexible polyester dome switch assembly without a backer is typically .053" thick. (Backer thickness is typically .125".)

A polyester dome switch assembly with a PCB lower circuit is typically .105" thick.

1.9.4 Standard Switch Travel
Switch travel is typically .028" for a tactile membrane.

1.9.5 Actuation Force
Actuation force is 12 ounces ± 2 ounces for tactile membrane switches. The characteristics of the floating keyboard make it much easier to vary the feel of the unit.

1.9.6 Standard Tooling and Tolerance
The keyboard is tooled using steel rule dies. This method results in dimensional tolerances of ± .010".

More costly male/female hard tooling must be used to achieve dimensional tolerance of ± .005". The snappable protrusions on polyester dome assemblies require match mold sets, increasing tooling costs. In addition, injection molding is required for the living hinge frame assembly.

1.9.7 Operating and Storage Temperature
Operating and storage temperature ranges from −40°C to 85°C.

Note
Extreme temperatures result in variation in the feel of the keyboard.

1.9.8 Contact Bounce
Contact bounce conforms to the standard for tactile membrane (Section 1.2) and metal dome keyboards (Section 1.5).

1.9.9 Encoding
In most cases, the following circuit layouts can be used with tactile membrane switches:

- x/y
- Common buss
- 2 pole
- 3 pole
- 4 pole

Note
Three and four pole circuits often require a specially shaped actuator. In addition, they have limitations placed upon contact bounce and density of layout.

The following circuit layouts can be used with metal dome switches:

- x/y
- Common buss
- 2 pole

1.9.10 Electrical
The maximum circuit rating is 30V DC, 100 milliamps, 1 watt.

1.9.11 Life Expectancy
A tactile floating key assembly conforms to the standard for tactile membrane (3 million closures).

Chapter 2
Circuit Construction

Although circuit construction need not be specified to the manufacturer, you should consider the following areas when preparing an application feasibility study or cost estimate:

- Circuit encoding
- Circuit interface/termination
- Touch sensation (flat or tactile)
- Environmental requirements
- Price objectives

This chapter describes four different types of circuit construction:

1 Single fold circuit
2 No fold circuit
3 Rigid lower circuit

2.1 Single Fold Circuit

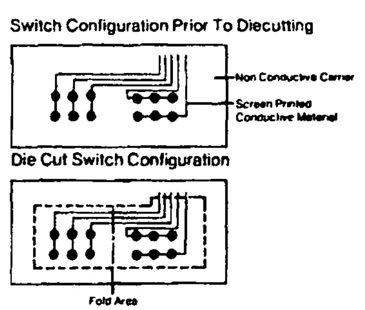
The single fold circuit has the advantage of low cost due to the relative simplicity of the construction technique.

2.1.1 Construction

The substrate consists of a single sheet of thin, non-conductive polyester or polycarbonate material. The upper and lower circuit routings are deposited on one side of the substrate. This entire process is done in a single screen-printing operation.

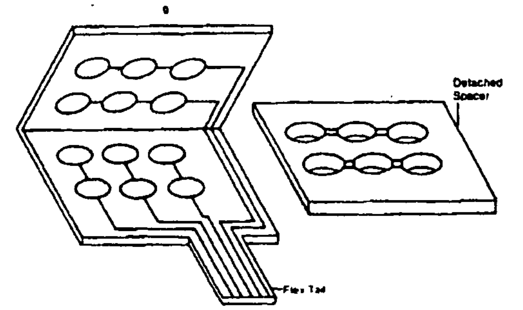
After the conductive ink has been properly cured, the entire circuit is then die cut to the specific keyboard configuration, as illustrated in the following figure:

Single Fold Circuit



Once die cut into the proper configuration, an insulating spacer layer is placed on the lower circuit and then the upper circuit is folded on top of the spacer. The three individual layers are secured by either laminate adhesives or, sonic welding or heat staking.

Single Fold Circuit



2.1.2 Closure

When pressure is applied to a switch location, the upper circuit flexes through cutouts in the spacer layer. This action results in momentary contact with the lower circuit, closing the switch.

The force required for switch closure depends on the diameter of the openings cut in the spacer layer.

The total distance travelled by the upper circuit during switch closure is determined by the thickness of the spacer layer and adhesives (if used). Upper circuit dome height of tactile membrane switches will also determine total switch travel.

Typically, internal venting channels are used to ensure air pressure equalization during switch closure. The venting channels cut into the spacer layer connect switch locations, allowing air to be shunted between groups of switch locations as necessary. (Refer to Chapter 4 for more detail.)

2.1.3 Sealing

It is highly recommended that the assembly be environmentally sealed in order to protect it against humidity, dirt, and liquid spills. Environmental sealing is achieved by applying an acrylic adhesive to both sides of the spacer layer.

Should sealed integrity be unnecessary, then heat staking or ultrasonic welding can be used to bond the three keyboard layers.

(Chapter 5 describes the process of switch bonding in detail.)

2.1.4 Electro-static Discharge

Because both the upper and lower circuits are printed on a single sheet of non-conductive material, some of the conductive routing must run across the circuit fold. This folded area is more susceptible to electro-static discharge than other areas of the keyboard.

(Chapter 8 discusses E.S.D. in detail and presents shielding alternatives.)

2.2 No Fold Circuit

The no fold circuit has two distinct advantages over the circuits already mentioned:

1 Its construction allows for less complicated circuit routing with increased circuit functions.

2 It offers better protection against environmental contaminants and electro-static discharge.

However, because of its added manufacturing time, the no fold circuit is somewhat more costly than single circuits.

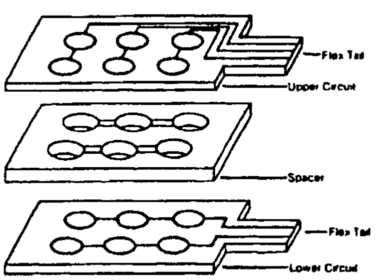
2.2.1 Construction

The no fold circuit consists of three sheets of thin, non-conductive polyester or polycarbonate material. Two of the sheets are screen-printed with conductive ink, which defines the circuit routing. These sheets serve as the upper and lower circuits.

The unprinted sheet makes up the spacer layer. Openings are cut into the spacer layer at each switch location. These spacer holes provide a point at which the upper and lower circuits can make contact.

After the conductive ink has been properly cured, the upper and lower circuits are die cut to the specific keyboard configuration. The spacer layer is then positioned over the lower circuit and the upper circuit is placed over the spacer layer. The assembly is secured either by adhesives or by sonic welding or heat staking.

No Fold Circuit



The no fold construction technique typically results in a circuit design with two separate flextails: one from the upper and lower circuit. These flextails are brought out to create one total tail width. Since the circuit traces on these tails face in opposite layers, it is recommended that a crimp through connector is used, such as a Berg single row series #65801. (Refer to Chapter 9 for more detail.)

2.2.2 Closure

When pressure is applied to a switch location, the upper circuit flexes through cutouts in the spacer layer. This action results in momentary contact with the lower circuit, closing the switch.

The force required for switch closure depends on the diameter of the openings cut in the spacer layer.

The total distance travelled by the upper circuit during switch closure is determined by the thickness of the spacer layer and adhesives (if used). Upper circuit dome height of tactile membrane switches will also determine total switch travel.

Typically, internal venting channels are used to ensure air pressure equalization during switch closure. The venting channels cut into the spacer layer connect switch locations, allowing air to be shunted between groups of switch locations as necessary. (Refer to Chapter 4 for more detail.)

2.2.3 Sealing

It is highly recommended that the assembly be environmentally sealed in order to protect it against humidity, dirt, and liquid spills. Environmental sealing is achieved by applying an acrylic adhesive to both sides of the spacer layer.

Should sealed integrity be unnecessary, then heat staking or ultrasonic welding can be used to position the three keyboard layers.

(Chapter 5 describes the process of switch bonding in detail.)

2.2.4 Electro-static Discharge

The lack of circuit folds and the use of recommended laminated acrylic adhesive bonding means that this assembly offers greater protection from electro-static discharge than folded units. Moreover, each additional layer of the construction increases the dielectric hardness of the keyboard. (Chapter 8 discusses E.S.D. in detail.)

2.3 Rigid Lower Circuit
Rigid lower circuit construction permits more complex circuit functions and the additional space on the PCB simplifies the actual circuit routing. This lower circuit typically consists of either a single or double sided printed circuit board, which enables the keyboard to incorporate metal domes and/or electronic components.

2.3.1 Construction
In this construction, a glass epoxy printed circuit board (PCB) is used as the lower circuit. For membrane keyboards, the upper circuit consists of either a polyester or polycarbonate material with construction and operation the same as previously discussed.

For metal dome keyboards, snap-action metal domes bridge the contact points on the lower PCB layer. The metal dome construction requires additional location and retainer layers to hold the domes in place. An optional actuation layer placed over the metal domes improves their snap-action.

Internal venting is also recommended, but not required for metal dome construction. Venting is achieved by cutting air channels in the location layer so that air pressure will be equalized when pressure is applied to the switch location, flexing the metal dome.

The keyboard can be enhanced by affixing electronic components to the front or rear of the PCB. These components can include integrated circuits, timers, axial light-emitting diodes, and seven segment displays.

2.3.2 Closure
For membrane keyboards, the upper circuit flexes through cutouts in the spacer layer when pressure is applied to a switch location. This action results in momentary contact with the PCB lower circuit, closing the switch.

The force required for switch closure depends on the diameter of the openings cut in the spacer layer.

The total distance travelled by the upper circuit during switch closure is determined by the thickness of the spacer layer and adhesives (if used). Upper circuit dome height of tactile membrane switches will also determine total switch travel.

Typically, internal venting channels are used to ensure air pressure equalization during switch closure. The venting channels cut into the spacer layer connect switch locations, allowing air to be shunted between groups of switch locations as necessary. (Refer to Chapter 4 for more detail.)

An alternative to a membrane upper circuit is snap-action metal domes. These domes are placed over plated contact perimeters on the PCB. Contact results when pressure is applied to the dome and it flexes to a plated contact center on the PCB.

In addition, the dome provides tactile feedback as pressure is applied and released, producing a distinct snap-action feel.

2.3.3 Sealing
It is highly recommended that the assembly be environmentally sealed in order to protect it against humidity, dirt, and liquid spills. Environmental sealing is achieved by applying an acrylic adhesive to both sides of the spacer layer, the PCB, and all associated retainer and actuator layers.

2.3.4 Electro-static Discharge
Protection against electro-static discharge can be greatly enhanced by adding laminated layers to the construction. Additional components, such as window displays or electronics, create E.S.D. points of entry. An E.S.D. shield can be incorporated into the keyboard to alleviate the danger to internal electronics. (Refer to Chapter 8 on E.S.D. protection.)

2.4 Half Switch
If the customer intends to provide a rigid PCB as the lower circuit layer, membrane manufactures will generally supply a unit consisting of only the upper circuit, spacer layer, and/or a graphic overlay for assembly to the customer's PCB. This package is referred to as a half switch.

Flat membrane and tactile membrane keyboards can be produced in half switch configurations. When assembled with the independently-supplied lower circuit, this unit functions like those described in earlier sections of this chapter.

Additional cost savings can be obtained by printing the graphics on the outer surface of a single sheet of non-conductive material. The upper circuit (shorting pad) is then printed on the inner surface of the same sheet. Although less costly, this method may prove to be less durable because the printed graphics are exposed to operational and environmental wear. A low cost polyester/polycarbonate over laminate may be applied over the exposed graphics to protect against wear.

Chapter 3
Encoding Techniques

Encoding is the assignment of electrical impulses to specific key locations on a membrane keyboard.

This chapter discusses the following encoding techniques:

- X/Y matrix
- Common buss
- Two pole/common
- Three pole/common
- Analog output

More information about circuit design and routing specifications can be found in Chapter 7.

3.1 X/Y Matrix

An x/y encoding matrix consists of high/low impulse leads that are arranged in rows and columns on opposite circuit layers. Each x and y intersection designates a discrete switch location.

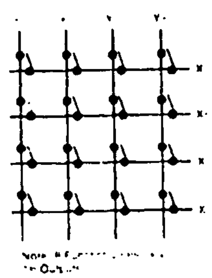
This matrix design can be used in conjunction with four constructions:

1 Single fold
2 Two fold
3 No fold
4 Metal dome

Typical X/Y Coordinance Grid

	X_0	X_1	X_2	X_3
Y_0	START	STOP	ENTER	RESET
Y_1	1	2	3	4
Y_2	5	6	7	8
Y_3	9	0	#	*

X/Y Matrix



The x/y matrix provides a maximum number of switch locations with a minimum number of termination leads.

3.2 Common Buss

Common buss encoding consists of one common (or ground) lead for all switch locations or groups of switches. Added to this is a single discrete lead or impulse line for each switch location.

When using common buss encoding, you must consider the total circuit routing area available. Densely populated switch configurations may not provide adequate area for interface/termination exit.

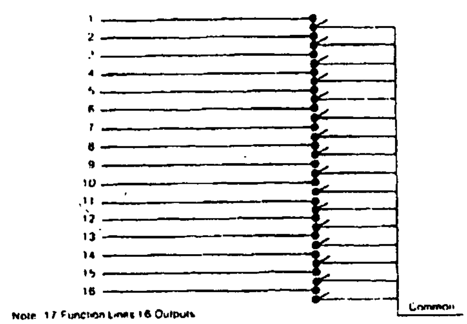
The common buss design can be used in conjunction with four constructions:

1 Single fold
2 Two fold
3 No fold
4 Metal dome

Typical Common Buss Coordinance Grid

Line Input	Location	Common
1	START	
2	STOP	
3	ENTER	
4	RESET	
5	1	
6	2	
7	3	
8	4	
9	5	
10	6	
11	7	
12	8	
13	9	
14	0	
15	#	
16	*	

Common Buss



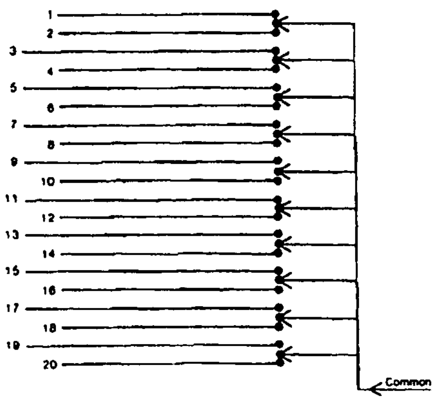
Chapter 7 contains additional design data.

3.3 Two Pole/Common

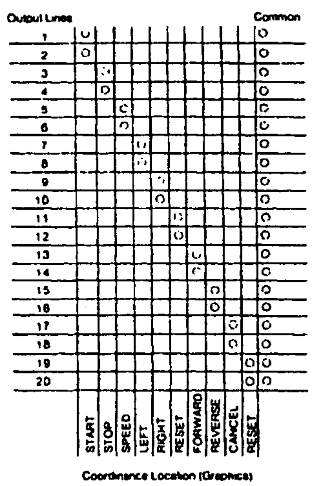
Two pole/common encoding consists of two discrete impulses. The common may be a singular impulse for all switch locations or consist of several common groups.

When specifying two pole/common encoding, you must consider the total circuit routing area available. Densely populated switch configurations may not provide an adequate area for interface/termination exit.

Two Pole Function Lines Plus Common



Typical Two Pole Coordinance Grid



The two pole/common design can be used in conjunction with three constructions:

1 Single fold
2 Two fold
3 No fold

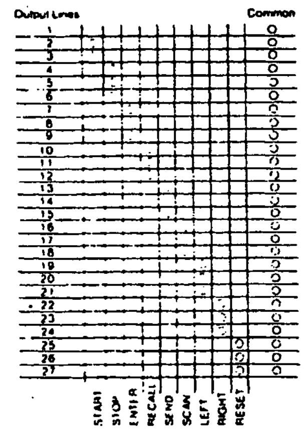
Chapter 7 contains additional design data.

3.4 Three Pole/Common
Three pole/common encoding consists of three discrete impulses for each switch location. The common may be a singular impulse for all switch locations or consist of several common groups.

When specifying three pole/common encoding, you must consider the total circuit routing area available. Densely populated switch configurations may not provide an adequate area for interface/termination exit.

The three pole/common design can be used in conjunction with three types of construction:
1 Single fold
2 Two fold
3 No fold

Typical Three Pole Coordinance Grid



Note that mechanical switch actuators may be required in three pole encodings to reduce contact bounce and/or total run time of switch closures. (See Sections 1.6, 1.7, 1.8, and 1.9 for additional information about mechanical actuators.)

As with two pole/common encoding, neither metal dome nor transparent technology can be used with three pole/common encoding.

3.5 Analog Output
Analog output consists of constant resistive values of various levels at discrete locations on a keyboard. By determining the resistance level at specific points on the keyboard, the electronic interface processor can identify a particular location.

Analog encodings are frequently used in transparent membrane technologies, which are often placed over display devices such as CRTs, plasma-gas displays, and electro-luminesent displays.

A major characteristic of an analog switch is its high resolution or switch location definition. An important factor in the resolution is also the electronic interface used. Resolution as low as .040" is possible in many cases.

Another benefit of analog is the minimum number of output lines: typically two or four. This figure depends somewhat on size and resolution requirements.

The analog output design can be used in conjunction with two constructions:

1 Single fold
2 No fold

In addition, analog outputs can be used with non-transparent switches to produce slide-activated switches or potentiometers, scratch pads, and cursor controls.

Chapter 4
Venting

When a keypad is depressed, air pressure within the switch cavity increases. In order for the switch to close properly, air within a switch cavity must be displaced, equalizing the internal pressure.

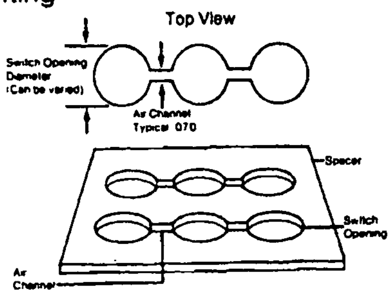
With an environmentally sealed keyboard, a laminate acrylic adhesive is used on each side of the spacer layer. However, environmental sealing traps the air in the switch cutouts of the spacer layer, meaning that the problem of equalizing this trapped air must be addressed.

Keyboards that are not environmentally sealed do not typically require venting because their open design allows air within a switch cavity to be displaced between the keyboard layers.

This chapter discusses two standard methods of venting environmentally sealed keyboards: internal and external.

4.1 Internal Venting
Environmental sealing of membrane keyboards represents an advantage over traditional mechanical switches and is strongly recommended. A sealed membrane keyboard offers increased protection from environmental contaminants such as dirt, moisture, and electro-static discharge. This seal provides for greater reliability at a relatively low cost.

Venting



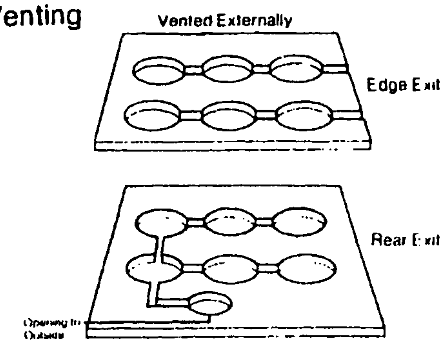
Vented Internally

4.1.1 Construction
When the keyboard has been sealed with a laminate adhesive, internal venting is required for both flat and tactile membrane constructions. Narrow channels between key location cutouts are cut in the spacer layer, permitting air from one key location to move elsewhere when that key is pressed. Note, however, that these air channels never exit to the outside of the keyboard, preventing the risk of contamination since the keyboard remains sealed.

Metal dome keyboards do not always require air channels, but may be necessary for some designs. In such cases, air channels that connect several metal dome locations are cut in the dome location layer and perform the same function as mentioned above.

4.2 External Venting
Because external venting increases the risk of contamination, it is only recommended when the keyboard will be exposed to rapid or extreme atmospheric pressure fluctuations and will not generally come into contact with a hostile environment. All types of keyboard constructions can accommodate external venting.

Venting



4.2.1 Construction
As in internal venting, narrow channels that have been cut into the spacer layer connect each key location. These channels then exit through the sides or rear of the keyboard. This design allows pressure within the switch cavities to be equalized with the surrounding atmosphere, thus allowing switch closure at any atmospheric pressure.

Non-adhesive bonded assemblies are externally vented by the nature of their construction

4.2.2 Contamination
External venting increases the chances of environmental contamination by dust, oils, chemicals, and moisture. In particular, an electro-static discharge flashover charge of 15K volts or less may enter the external venting channel, follow the conductive circuitry, and damage sensitive internal components.

Methods of shielding against electro-static discharge are discussed in Chapter 8

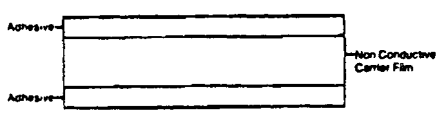
Chapter 5
Switch Bonding

Switch bonding refers to the method selected for securing all independent layers of a keyboard, including the upper and lower circuits. When choosing a bonding technique, environmental considerations are important since the performance of a switch depends largely on the integrity of its bonding.

5.1 Adhesives
The acrylic adhesive group is widely accepted in membrane switch construction because of its high bond strength, performance range, and ease of application.

In a typical flat membrane construction, the pressure-sensitive acrylic adhesive is applied to both sides of the insulating spacer. This spacer is then positioned between the upper and lower circuits to provide total switch bonding.

Support Adhesive Layer
Cross-Section



Bond strength increases in relation to time and temperature. Seventy-six percent of total bond is achieved within 72 hours after the final assembly of the layers. However, the remaining or ultimate adhesion takes place during the next nine months.

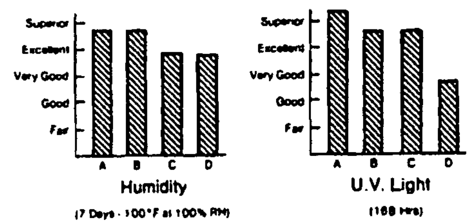
Unique performance or environmental requirements may demand that special bondings be used, such as heat or chemically activated adhesives.

Note
When applying the adhesive, it is critical that proper surface wetting and bonding occurs. The adhesive should blow or level out to reduce the number of air bubbles. This procedure excludes contaminants and increases the protection against E.S.D. through the spacer layer.

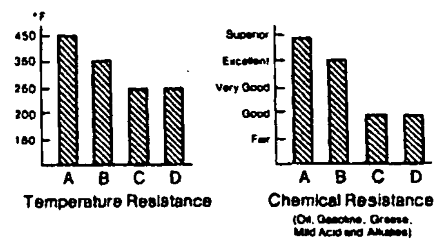
Wetting is defined by a compatibility between the surface tension of the substrate and the adhesive.

Information about proper bonding adhesives can be analyzed by referring to the following charts:

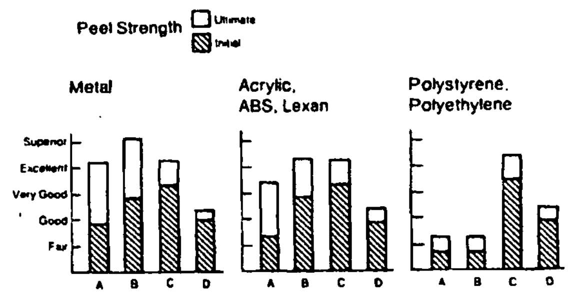
Adhesives
Environmental Performance



Adhesives



Adhesives



Legend
A = High Temperature
B = High Performance
C = High Strength
D = High Tack

5.2 Heat Staking
A non-adhesive bonded switch assembly can be produced by the use of heat stakes. This method can reduce the cost of the switch, but this advantage must be weighed against the loss of environmental sealing. The problems of electro-static discharge and contaminants found in the proposed operating environment should be considered before a final decision is reached.

The heat staking process involves the following steps:

1 The lower circuit, spacer layer, and upper circuit are mounted on a plastic substrate which is typically the backer or mounting surface for the switch assembly.

2 These layers are mounted over pins which have been fabricated into the rigid backer.

Holes in the upper circuit, spacer layer, and lower circuit accommodate the pins located on the plastic backer. The size of the part determines the number of pins required.

3 Heat and pressure are then applied to the pins which protrude through the switch layers. This causes the pins to melt over the upper layer, resulting in a point bonding of the switch assembly to the plastic backer.

Note that this method allows potential electro-static discharge flashover to enter between the laminates at the switch assembly perimeters. Overall switch performance and E.S.D. protection are significantly improved by concealing perimeter edges with a bezel or gasket seal.

5.3 Ultrasonic Welding
Ultrasonic welding utilizes high-frequency sound waves to bond the layers of the assembly. Consequently, no pins or plastic backer are required for this method of bonding.

The insulating spacer is positioned between the upper and lower circuits and is welded at several points. The high-frequency sound waves produce heat that causes the material to bond at selected points. However, all the switch layers must be chemically compatible and have melting temperatures within 35°F of each other.

Bond strength of a weld point is typically as high as 95% of the original materials bonded.

Like heat staking, ultrasonic welding allows potential electro-static discharge flashover to enter between the laminates at the switch assembly perimeters. Overall switch performance and E.S.D. protection are significantly improved by concealing perimeter edges with a bezel or gasket seal.

Chapter 6
Conductive Materials

This chapter discusses the characteristics of several electrical carriers used in membrane switch construction. They include:

- Silver conductives
- Carbon conductives
- Gold conductives
- Indium tin oxide conductives
- Copper conductives
- Nickel conductives
- Tin/lead conductives
- Palladium conductives
- Metal dome conductives

6.1 Silver Conductive Ink
Silver conductive ink is the preferred electrical carrier for polyester and polycarbonate membrane construction. Silver inks have many inherent advantages:

- Favorable conductivity to cost ratio
- Ease of application
- Ductility
- Resistance to flaking
- Long term reliability

6.1.1 Manufacture
Silver conductive inks are manufactured by blending fine silver particles in an epoxy binder to form a homogeneous polymer. The standard concentration of silver particles is 63%, but can be altered as cost requirements dictate. Keep in mind, however, that resistivity is inversely proportional to the silver concentration.

Inks with a 63% silver concentration have a typical sheet resistivity of .010 to .012 ohms per square mil..

6.1.2 Curing
Once deposited on the polyester or polycarbonate substrate, proper curing of the ink is critical. The process of curing the freshly deposited epoxy-base polymer involves exposing the conductive inks to dry heat at 100°C for an extended period of time.

Proper curing results in consistent resistivity, substrate adhesion, and lack of flaking even when folded. On the other hand, improperly cured inks are subject to flaking, poor ductility, and increased resistivity.

6.1.3 Resistivity
A fold endurance test developed by M.I.T. demonstrates the ductility of properly cured conductive inks. This test measures ductility as a function of circuit resistivity. A conductive circuit at 50 ohms/sq./mil. resistivity increases to only 90 ohms/sq./mil. after 200 270° folds.

Silver Conductive Material Product Characteristics

Test	Method	Units	Results
Sheet Resistivity	OHM meter	OHMS/Sq/Mil	.010-.012
Resistivity after flex crease (180° one cycle)	OHM meter 15 sec. after test	OHMS/Sq/Mil	.050
Fold (270° 200 cycles)	MIT fold endurance test 15 sec. after test	OHMS/Sq/Mil	.090
Resistivity After Thermal Shock			
Dry Heat	80°C, 10 days, 5 cycles 1/2 hour each, 3M oven	OHMS/Sq/Mil	.090
Humidity	Mil Standard 202E Method 103, Condition A—40°C/95% RH, 10 days, 5 cycles 1/2 hour each	OHMS/Sq/Mil	.09-.100
Tape Adhesion (after both tests)	3M tape No. 810	Visual	Excellent
Fingernail Scratch Resistance	Moderate pressure	Visual	Excellent
Abrasion Resistance (pencil borders)	ASTMD 3363-74		2H
Adhesion/ tape pull	3M Scotch tape No. 810	Visual	Excellent
Silver Migration	Mil Std. 202, 106D, 2 cycles/ day 22°C (68°F)-65°C (150°F), 90-95% RH, 5DC volts after 10 days	25 Mil lines equal spacing & 8 Mil lines equal spacing	No change from arcing or shorting out.
Sulphur	38 milligrams sulphur in one cubic ft. chamber 50°C, 80% RH for 10 days to create sulphur dioxide environment	OHMS/Sq/Mil	No loss in resistance: noted discoloration
Salt Spray	ASTM B117 95°F, 5% salt solution, 10 dyas	OHMS/Sq/Mil	Initial: .0118 After salt test: .08 Initial after crease: .050 After crease and salt test: .011

6.1.4 Cost Extending Silver
Should unit cost be an overriding concern, carbon or epoxy fillers may be added to silver conductive inks. This process lowers the silver concentration and thus lowers the materials cost. However, circuit performance is also lowered due to increased resistivity.

6.1.5 Silver Migration
Silver migration can be thought of as a form of leaching which causes the silver particles to separate from the epoxy polymer. Areas that have experienced migration become points of increased resistivity and potential shorting.

Silver migration is of concern when dealing with non-sealed keyboards, or keyboards with external venting.

Silver migration may occur under high humidity. This migration can be inhibited by depositing a carbon layer over the silver conductive routing. This carbon layer forms a barrier that decreases the chance of migration.

External switch components, such as termination/interface flextails, are particularly prone to silver migration due to their exposure to environmental moisture. Consequently, additional protection is strongly recommended.

Carbon overcoating of the entire circuit routing is advised for non-adhesively sealed keyboards because they are subject to environmental moisture. However, this additional manufacturing step increases unit cost. The carbon overcoating process is described in Section 6.2.3.

6.2 Carbon Conductives
Carbon conductive ink serves as an alternate electrical carrier for polyester and polycarbonate membrane construction. These inks have the advantage of reduced cost when compared to silver inks.

However, carbon conductive inks also have higher resistivity. For that reason, their use is limited to applications that can accommodate high resistance values.

6.2.1 Manufacture
Carbon conductive inks are manufactured by blending fine carbon particles in an epoxy binder to form a homogeneous polymer. Desired circuit resistivity dictates the concentration of carbon particles

Carbon ink resistivity is inversely proportional to carbon particle concentration.

6.2.2 Curing
Once deposited on the polyester or polycarbonate substrate, proper curing of the ink is critical. The process of curing the freshly deposited epoxy base polymer involves exposing the conductive inks to dry heat at 100°C for an extended period of time.

Proper curing results in consistent resistivity, substrate adhesion, and lack of flaking even when folded. On the other hand, improperly cured inks are subject to flaking, poor ductility, and increased resistivity.

6.2.3 Overcoating
Carbon inks often serve as a protective coat for exposed silver conductive ink circuitry. This carbon coating restrains silver particles from migrating out of the silver epoxy polymer, and forming an area for potential short. Silver migration prevention should be considered if the keyboard may be exposed to environmental moisture and high humidity.

Vulnerable areas that may require a carbon coating are non-adhesively sealed keyboards, circuit routing exposed through external venting, and termination/interface flextails.

Note
If migration is of concern in your application, you should strongly consider a protective carbon coating.

(Refer to Section 6.1.5 for more information about migration.)

6.2.4 Resistor Usage
In addition to other applications, carbon conductive inks are sometimes used as low cost circuit resistors. Voltage step down, or the lowering of line voltage through increased resistance, is achieved when a specific amount of carbon ink is deposited at a point in the circuit. Light Emitting Diodes (L.E.D.s) require low voltage and may now be driven directly by circuits without a separate resistor.

6.3 Gold Conductive
Gold as a conductor is the most efficient electrical carrier. Due to gold's substantially higher cost, it is primarily used when stringent environmental factors are present or high performance is desired.

Gold contact points or gold plating over silver conductives may be used in flexible membrane keyboards and nickel/gold plating in rigid PCB-backed keyboards.

Gold contact points improve switch performance by reducing contact bounce. Values as low as 1 millisecond may be achieved.

6.3.1 Gold and Silver Interface
Both gold and silver are low-resistance current carriers. However, they are not compatible, and a carbon polymer or other conductive material is recommended to chemically separate when they are used together.

The carbon polymer or other conductive material prevents silver from migrating into the gold layer which could cause the production of a non-conductive alloy at the interface of the two metals.

Although gold can be plated over silver, it is not recommended due to the added cost and questionable performance improvements. Gold/silver migration greatly accelerates after 10,000 switch closures

6.4 Copper
Copper conductive inks serve as an alternative to silver conductive inks.

Although a good conductor, copper suffers from two serious weaknesses:

1 Copper's cost/performance ratio is not as attractive as silver. (This ratio is defined as the cost of metal versus its ability to act as an electrical carrier.)

2 Copper conductive inks are subject to continued oxidation when exposed to the environment. This factor limits their effectiveness.

Risk of oxidation can be eliminated by applying a carbon polymer coating over the copper circuitry. However, this additional manufacturing step erodes copper's initial cost advantage over silver.

Note
Etched copper printed circuit boards or flexible circuitry are manufactured using an entirely different process. They are widely accepted as conductive carriers.

6.5 Nickel
Nickel conductive ink is a low cost alternative to silver conductive inks. However, nickel has an inherently high resistance value.

Nickel has proven to be an effective electrical carrier in applications such as low cost electro-static discharge shielding where exposure to high temperature operating environments is not a factor.

In addition, nickel is less vulnerable to oxidation than copper, making it more effective when used in non-sealed keyboards.

Nickel conductive inks are epoxy polymer-based and are manufactured using the same process as silver inks. (Refer to Section 6.1.1 for more detail.)

6.6 Tin/Lead
Tin/lead plating is typically used as contact points on PCBs.

Tin/lead's conductivity and resistance value are generally acceptable for most PCB applications. In addition, oxidation is not a factor.

Contact bounce averages five milliseconds or less. Should lower contact bounce time be required, gold is the recommended plating on contact points. Refer to Section 6.3..

6.7 Palladium
Palladium, suspended in an epoxy polymer applied over silver conductives, was originally developed to prevent silver migration of conductive circuits on ceramic substrates.

However, palladium applied over silver conductives on flexible membrane circuits has proven to be unsuccessful. The high baking temperatures required to cure palladium properly are above the melting points of the polyester or polycarbonate plastic films used in membrane keyboard substrates.

Section 6.2.3 provides more information about methods for combatting silver migration.

6.8 Metal Domes
Metal dome contacts usually consist of stamped stainless steel domes.

Stainless Steel Metal Domes are typically classified as either:

Contact Type

Non-Contact Type

Within these two categories a wide variety of materials, actuation forces and sizes exist. Although the selection of the dome type is application specific and should be left to the keyboard manufacturer, it is important to note that the proper dome type, ie. contact type or non-contact type, is used with the appropriate construction technique.

Chapter 7
Circuit Design

When designing keyboard circuitry the following factors should be considered:

- Circuit encoding
- Circuit interface/termination
- Touch sensation (flat or tactile)
- Price objectives
- Material selection

By determining factors such as lead routing, key spacing, and dome height, a more precise keyboard specification can be developed. Keep in mind that the final circuit design is normally the responsibility of the manufacturer.

This chapter discusses four circuit types:

1 Flat membrane
2 Tactile membrane
3 Printed circuit board (metal domes)

7.1 Flat Membrane

Flat membrane circuits can be constructed using the following fabrication techniques:

- Single fold
- No fold

This decision depends largely on the density of the internal circuit routing. If common buss, two pole, or three pole encoding is used, the routing will be relatively dense.

You can formulate the capacity of a particular design by establishing a minimum edge to trace distance, keypad diameter, keypad spacings, openings for displays, L.E.D.s, or other keyboard electronics and interface/termination exit.

The total resistance value of a conductor may be determined by multiplying the total cross-sectional area of the conductive traces by the conductor's length. The cross-sectional area is inversely proportional to its total resistance value. In contrast, the conductor length is proportional to its resistance value.

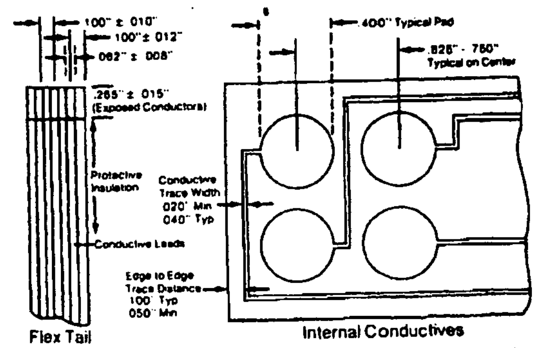
To further estimate this figure, refer to Chapter 6, which discusses conductive materials. Choose the appropriate conductive material for the application and determine its ohms per sq. resistive value. (Note that these values are typically given for a thickness of 1 mil.) Since most membrane circuit routings are 1/2 mil., double the given resistive value.

Next determine the length of the run or lead and calculate its average width. Divide the average width into the length and multiply by the resistance value. The result is the resistivity for that particular lead. Be sure to include the flextail length when making the calculation.

Conductive lead spacings on flextail interface/termination routing are typically 0.100" with standard routing widths of 0.50" to 0.62".

Note: The minimum bend radius on a flex-tail is .100". Should the application require sharp folds and/or bends, the keyboard manufacturer should be alerted to this during the design cycle to allow for the compression or expansion of the conductive materials.

Circuit Design



Note Max distance of conductive trace to edge provides best Electro Static Discharge Protection

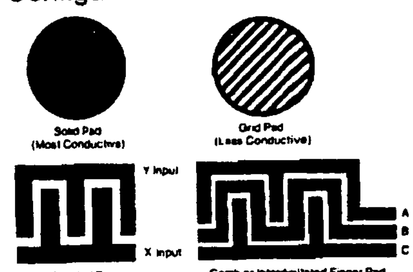
Note
The length of the flextail and the type of connector substantially affect the cost of the switch. (Further information about termination hardware can be found in Chapter 9.)

Contact pad configurations include solid, grid, and two or three finger interdigitated types. Solid contact pads are commonly used in x/y and common buss designs. Grid contact pads are designed to be used in place of solid pads; this technique conserves material and thus lowers cost.

Interdigitated pads allow for two or three inputs to appear on the same surface at specific switch locations. Interdigitated pads are used in conjunction with the following encoding techniques:

- Common buss
- Two pole
- Three pole

Pad Configurations



Protection against electro-static discharge can be increased by maintaining the maximum amount of distance between the circuit and the edge of the keyboard.

7.2 Tactile Membrane
Tactile membrane circuits can be constructed using the following fabrication techniques:

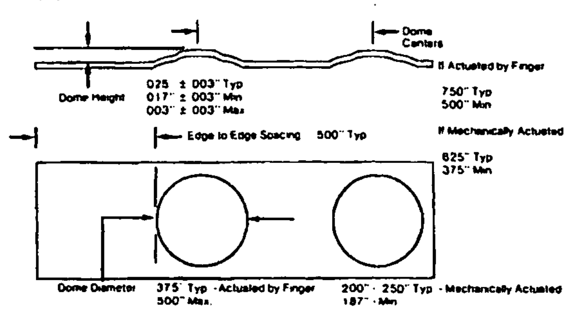
- Single fold
- No fold

This decision depends largely on the density of the internal circuit routing. If common buss, two pole, or three pole encoding is used, then the routing will be relatively dense.

As described in Section 1.2, the tactile membrane consists of a basic flat membrane with a domed upper circuit. This domed circuit provides tactile feedback and keypad location.

Tactile/Membrane

Cross-Section



Note: The minimum bend radius on a flex-tail is .100". Should the application require sharp folds and/or bends, the keyboard manufacturer should be alerted to this during the design cycle to allow for the compression or expansion of the conductive materials.

Dome height and method of actuation determine the intensity of the tactile feedback. Although actuation force is typically 8 to 12 ounces, this value can be altered to meet specific switch requirements.

Tactile membrane construction can be used with the following types of contact pads:

- Solid
- Grid
- Two or three finger interdigitated

Solid pads are often used in x/y and common buss designs. Grid contact pads are designed to be used in place of solid pads; this technique conserves material and thus lowers cost.

Interdigitated pads permit two or three inputs per switch to appear on the same surface at specific switch locations. Should run time (the time required to close multiple switches as measured by a microprocessor) or contact bounce increase unacceptably when using interdigitated pads, mechanical actuators can be used to produce a more positive depression of the membrane and switch contacts. (See Sections 1.6 - 1.9)

Laminate acrylic adhesive bonding is recommended in all tactile membrane designs since heat staking and ultrasonic welding do not generally provide sufficient stability for the circuit.

Heat staking and ultrasonic welding both bond the keyboard layers in four to eight individual locations while laminate adhesives secure the entire surface. This bonding of the entire surface accounts for the added durability achieved with laminate acrylics

Spacing and resistive values are outlined in Section 7.1.

7.3 Printed Circuit Board (PCB)
Printed circuit boards are typically used as the rigid lower circuit in metal dome, flat membrane, and tactile membrane keyboards. By using a rigid PCB, lower contact bounce can be achieved. In addition, the PCB provides a rigid mounting structure for the keyboard that can accommodate electronic components

When choosing between a single or double-sided plated PCB you should consider the circuit routing density and encoding requirements

Circuit Design

Interdigitated finger pads are recommended for use on the PCB when a membrane keyboard is used. Shorting pads are typically used for the upper circuit of both flat and tactile membrane keyboards.

In metal dome/PCB construction, the printed circuit board's contact points consist of a plated perimeter conductor pad on which the "feet" of the dome sit. This perimeter pad acts as one half of the input conductor. A second plated conductive point on the PCB is located at the center of the perimeter conductor.

Contact results when pressure is applied to the dome and it flexes to a plated contact center on the PCB.

The following plating options are available for use with a copper-clad PCB:

- Tin/lead plate
- Nickel plate
- Nickel/gold plate

The choice depends upon required electrical performance, as well as cost and environmental factors.

When using a double-sided plated board, insulating solder masks can be used to protect exposed contact points.

Chapter 8
Electro-static Discharge/Radio Frequency Interference/Electro-magnetic Interference

8.1 Electro-static Discharge
Electro-static discharge or E.S.D. refers to the accumulation of static electricity on the surface of the human body. Friction between dissimilar insulating materials produces this electrical charge. For instance, walking on a rug and then touching a grounded object produces and transmits such a charge.

The usual voltage accumulation averages 10-15 KV, although it may reach as high as 50KV under ideal conditions. Low relative humidity, dissimilar materials with high friction, and large dry body surface area all result in voltage accumulation.

Effective E.S.D. protection must be built into keyboards that contain electrical impulse sensitive CMOS, MOS, and Bipolar I.C. switch components. Such components are used extensively in miniaturized intelligent and dumb controls. The need for electro-static discharge protection increases as keyboard applications move into the general marketplace where little attention is paid to discharge factors.

Protection of electronic components and keyboard assemblies against electro-static discharge can be achieved through either passive or active intervention.

Passive E.S.D. intervention consists of the successive buildup of the non-conductive layers of the upper keyboard without using independent grounding. By contrast, active E.S.D. intervention is produced by incorporating a separately grounded printed circuit between the graphic overlay and the upper circuit layer.

8.1.1 Passive E.S.D. Intervention
Passive E.S.D. intervention is recommended under two conditions:

1 The keyboard contains few sensitive electronic components.

2 Cost is a major factor.

The extent of the protection depends on several factors:

- Use of acrylic adhesive to seal the keyboard
- Type of keyboard termination
- Size and shape of the internal circuit routing
- Thickness and choice of construction material
- Presence of electronic display windows

A typical 0.015" to 0.020" thick sealed membrane keyboard provides 13-20KV "punch out" E.S.D. protection. Punch out E.S.D. is defined as the charge which passes directly through the plastic construction film and enters the internal circuit.

Each membrane layer added to the keyboard construction improves punch out resistance of the keyboard against E.S.D. entry. For these reasons, laminated acrylic adhesives of a sealed keyboard increase E.S.D. protection by a factor of 2 to 4 over heat staking or ultrasonic welding.

Electrical Dielectric Strength—
Non-Conductive Insulating Materials

Materials	Test Method	Volts/Mil
Polycarbonate	ASTM D149	1,400
Polyester	ASTM D149	3,330
High Density Polyethylene	ASTM D149	450-500
Low Density Polyethylene	ASTM D149	450-1,000
Polypropylene	ASTM D149	3,000-4,000

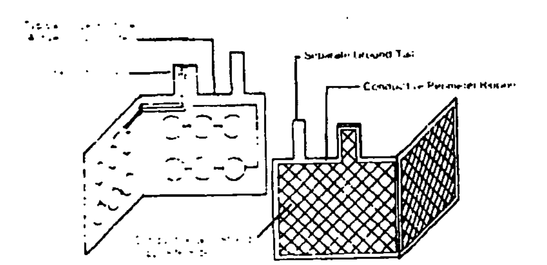
E.S.D. flashover is of greater concern than punch out. Flashover is defined as the charge that enters between the membrane layers at the perimeter of the keyboard or other points. These points include external venting ports, air gaps left in the laminate adhesives during manufacturing, and electronic display windows.

E.S.D. flashover often follows surface carbon tracks leading to perimeter entry points. These carbon tracks are formed during previous electro-static discharges. Consequently, each E.S.D. flashover lowers the keyboard's overall E.S.D. hardness. Once an E.S.D. flashover charge has penetrated the keyboard perimeter, it will enter the circuit routing generally at the closest circuit to the edge.

8.1.2 Active E.S.D. Intervention
Active E.S.D. protection consists of printing a separate electro-static shield of silver or nickel conductive inks on a non-conductive surface. This printed surface is located between the graphic overlay and upper circuit and is independently grounded so that an E.S.D. charge bypasses the vulnerable circuit components. The ground should be at earth potential or connected to either the product casing or the common side of a battery. E.S.D. protection in excess of 25KV is generally obtainable using this method.

Electro-Static Discharge Shield

Printed Conductive Grid Pattern On Folded Circuit

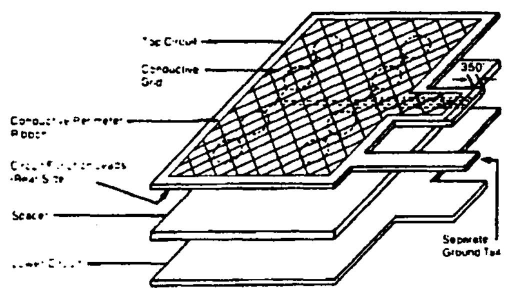


Electro-static Discharge/Radio Frequency Interference/Electro-magnetic Interference

The grounded electro-static shield significantly hardens the keyboard against either punch out or flashover damage. However, a particularly strong flashover may bypass the shield and enter the circuit routing at the perimeter. This risk can be eliminated by adding a non-conductive perimeter bezel or a conductive perimeter bezel that has been independently grounded in the same manner as the shield. (See Section 13.2.1.)

Electro-Static Discharge Shield

Printed Conductive Grid Pattern On A No Fold Circuit



8.1.3 E.S.D. Protection

E.S.D. protection should also be designed into a keyboard without the use of additional components by following these rules:

- Use acrylic laminate adhesives that add non-conductive layers and seal perimeter edges.
- Avoid air bubbles between laminates during construction.
- Locate individual switch pads prior to the circuit routing design.
- Place all circuit routing as far away from the keyboard edge as possible.
- Check the circuit routing design before finalizing the keyboard's visual design.

All of the above design considerations can be incorporated into the keyboard's construction by the manufacturer without compromising the appearance of the keyboard.

8.2 Radio Frequency Interference and Electro-Magnetic Interference

Radio Frequency Interference (RFI) and Electro-Magnetic Interference (EMI) consist of high and low frequency radio waves. Many computing devices emit such waves or are susceptible to interference from such waves including computer terminals and peripherals, as well as digital telephones. RFI emissions must be below levels prescribed by the FCC. These levels were established as of October 1983.

The following table shows the acceptable levels for Class A devices (intended for commercial, industrial, or business environments) and Class B devices (intended for general market or home use):

Specifications:
Radiated RFI is limited as follows:

Class A Computing Devices

Frequency (f) (MHz)	Distance (Meters)	Maximum Field Strength (uV/m)
30-88	30	30
68-216	30	50
216-100	30	70

Class B Computing Devices

Frequency (f) (MHz)	Distance (Meters)	Maximum Field Strength (uV/m)
30-88	3	100
88-216	3	150
216-1000	3	200

Conducted RFI is limited as follows:

	Maximum RF Line Voltage (db above 1 uV)	
Frequency (MHz)	**Class A**	**Class B**
0 45-1 6	60	48
1 6-30	69 5	48

Note Conducted limits in the frequency range of 10 to 450 KhZ are under consideration

Equipment operating in excess of 10,000 cycles per second emits a high frequency interference that can affect nearby television, radio, and communications receivers. The FCC standards of October 1983 were designed to counteract this problem.

RFI and EMI shielding of membrane keyboards is accomplished using techniques similar to those employed in combatting E.S.D. Additional layers of polycarbonate or polyester material sealed with laminate acrylic adhesives may provide sufficient RFI or EMI protection depending on the particular equipment the keyboard is connected to.

Care should be taken to provide additional protection to flexible termination/interface cables, which are a major source of RFI or EMI contamination. For low RFI or EMI emission sources, polycarbonate and polyester material extended over the flextail may be sufficient. When RFI or EMI emissions are strong, a variety of copper, thin metal, or steel mesh shielded flexible cables are available.

Additional internal RFI or EMI shielding of the keyboard itself is accomplished by incorporating a silver or nickel screen-printed conductive layer between the graphic overlay and the upper circuit. This conductive grid is manufactured by the same process as an E.S.D. shield and is independently grounded.

External shielding is accomplished by completely surrounding the keyboard and accompanying electronics with copper, aluminum, or stainless steel plates to ensure complete RFI or EMI containment.

Chapter 9
Interface and Termination

When selecting a method of connecting the keyboard to electronic components, the following factors should be considered:

- Cost
- Reliability
- Performance
- Design
- Environment
- Anticipated insertions and extractions

Mechanical specifications for most interface terminations are standard. Consequently, circuit construction techniques can be designed for compatibility with specific types of interface termination methods. The no fold circuit, for instance, consists of two flextails facing in opposite directions. As a result, only certain types of interface terminations are possible.

9.1 Exposed Conductors

In this method the keyboard is supplied with a flextail of specific length, which has exposed traces on its surface. The flextails can be either insulated or non-insulated up to the point of termination, depending on the requirements of the application.

Four connector types are commonly employed in this method:

1 AMP-Trio mate
2 AMP connector clip
3 Molex flat connectors
4 Precision Concepts flat connectors

These interface products serve as the receptacle portion of the termination and are mounted to a printed circuit board.

9.1.1 AMP-Trio Mate

The AMP-Trio mate is a low insertion, high extraction connector that can be used in either parallel or perpendicular PCB mounting. It accommodates up to 22 positions on a single connector.

The contacts are tin-plated phosphor bronze and are housed in a self-extinguishing terminal.

The contact design of the AMP-Trio mate permits it to accommodate all types of circuit flextails (i.e., exposed conductive material on separate flextails in opposing directions).

This connector system allows for opposing exposed conductors on a flex tail to make a gas tight connection of moderate costs.

AMP Trio-Mate Connector Specifications

Environmental Characteristics

Thermal Shock— −55°C and +85°C for conductive ink

Temperature/Humidity Cycling—10 temperature humidity cycles between 25° and 65°C at 95% RH

Industrial Gas—96 hours of 200 ppb each of nitrogen dioxide, sulfure dioxide and hydrogen sulfide

Electrical Characteristics

Dielectric Withstanding Voltage—1.5 kvac dielectric withstanding voltage. one minute hold

Insulation Resistance—5000 megohms min., initial

Capacitance—1.0 picofarads max.

Mechanical Characteristics

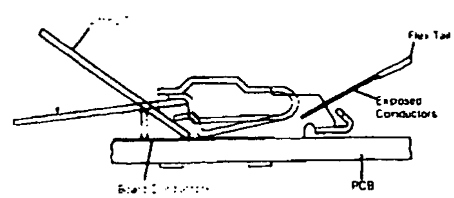
Vibration—10-55-10 Hz traversed in 1 min. at .06 [1.52] total excursion

Physical Shock—100 G's sawtooth in 6 milliseconds

9.1.2 AMP Connector Clip

The AMP connector clip holds the exposed conductors of a flextail in contact with the plated contacts on a printed circuit board. As such, it performs no electrical function.

Amp Connector Clip



The AMP connector clip can accommodate up to 13 positions. However, the design of this interface requires that all the exposed contacts of the flextail be on one side, generally limiting its use to single and two fold circuit designs. (Refer to Chapter 2.)

This connector system is the lowest cost type available.

AMP Connector Clip

Environmental Specifications

Thermal Shock—MIL-STD-1344 Method 1003.1; ten cycles between the extremes of −20°C and +105°C

Thermal Aging—MIL-STD-1344, Method 1005.1; 96 hrs. of continuous exposure at +85°C

Industrial Gas—10% SO_2 atmosphere for 24 hrs.

Humidity—MIL-STD-1344, Method 1002.2; 240 hrs. of temperature cycling and high humidity

Vibration—MIL-STD-1344, Method 2005.1; 12 hrs. of sinusoidal vibration between the frequency limits of 10 to 2000 hz at 20G acceleration

9.1.3 Molex 7583-CN

The Molex 7583-CN connector series is a non-gas-tight, low or high pressure contact system. It is available for either right angle or perpendicular PCB mounting.

The Molex 7583-CN can accommodate from 5 to 21 positions on a single connector. The contacts are tin-plated phosphor bronze and are housed in a self-extinguishing terminal.

The design of this interface requires that all the exposed contacts of the flextail be on one side, generally limiting its use to single and two fold circuit designs. (Refer to Chapter 2.)

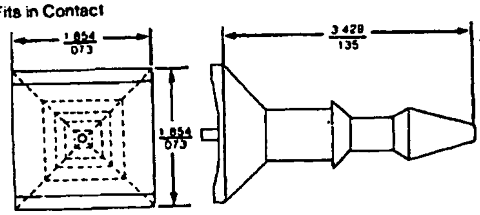
This connector system provides a locking method to hold the flextail in place is the connector at moderate costs.

Interface and Termination

Polarizing Key
A polarizing key is an option commonly used to plug an unused contact on a female terminal connector. This partially plugged terminal can now be connected in only one way.

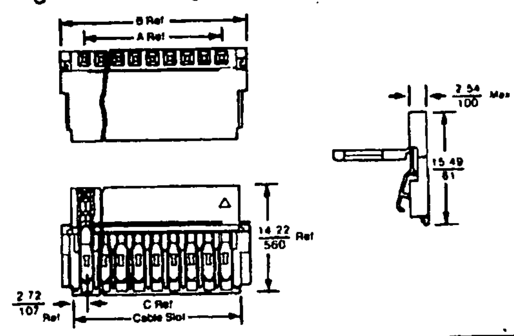
Polarizing Key

Fits in Contact



9.2 Single Row/Crimp Type
Single row/crimp connectors provide a gas-tight termination interface between a flextail and connector. In this method the keyboard is supplied with a flextail of specific length. Crimped to the flextail(s) is a male or female shrouded connector.

Single Row Berg



This connector is attached by inserting the flextail into a V-shaped opening that consists of a complex beryllium copper crimping contact. Once inserted, the opening is mechanically crimped to the flextail, forming an electrical contact and a gas-tight connection.

Crimping pierces through both sides of the flextail, allowing any of the circuit designs discussed in Chapter 2 to be used.

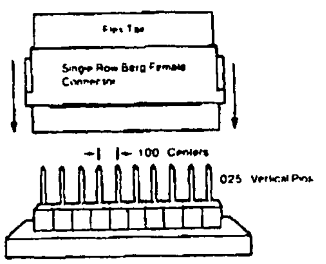
The cost of this interface depends on its contact plating material (tin/lead or gold) and the number of pins required.

The Berg Clincher 65801 is the most commonly used connector of this type and is available in either receptacle or pin type construction.

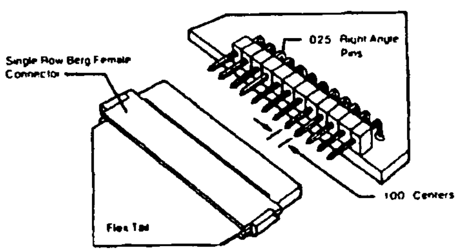
Interface and Termination

Both designs require that a separate interface device be soldered in place on the PCB. This interface device receives the clincher.

Berg Single Row Connector



Berg Single Row Connector



This connector system allows for a gas tight, shrouded connector attached directly to the flextail at moderate costs.

9.2.1 Berg Single Row

Physical Characteristics

Housing:
Material
Polypropylene, flame retardant per UL 94 V-0

Color: Blue

Contact:
Body Material:
1/2 Hd. Cupro-Nickel Alloy, UNS-C 72500

Body Plating:
2.54μm (100μ") min. thick 60/40 Tin-Lead
or
0.76μm (30μ") Gold plating in contact area

Spring Material:
1/2 Hd. heat-treated Beryllium Copper Alloy, UNS-C 17200

Spring Plating:
0.25μm (10μ") min. thick 60/40 Tin-Lead
or
0.51μm (20μ") min. thick Gold

Number of Positions	Part Numbers Tin-Lead	Part Numbers Gold
2	65801-002	658[illegible]
3	65801-003	658[illegible]
4	**65801-004**	**65[illegible]**
5	**65801-005**	658[illegible]
6	**65801-006**	**65[illegible]**
7	**65801-007**	6580[illegible]
8	**65801-008**	**65801-[illegible]**
9	**65801-009**	**65801-[illegible]**
10	**65801-010**	**65801-[illegible]**
11	**65801-011**	**65801-[illegible]**
12	**65801-012**	**65801-041**
13	**65801-013**	**65801-042**
14	**65801-014**	**65801-043**
15	**65801-015**	**65801-044**
16	**65801-016**	**65801-045**
17	**65801-017**	65801-0[illegible]
18	**65801-018**	**65801-047**
19	65801-019	65801-048
20	**65801-020**	**65801-049**
21	65801-021	65801-050
22	65801-022	65801-051
23	65801-023	65801-052
24	65801-024	65801-053
25	65801-025	65801-054
26	65801-026	65801-055
27	65801-027	65801-056
28	65801-028	65801-057
29	65801-029	65801-058
30	65801-030	65801-059
31	65801-031	65801-060
32	65801-032	65801-061

Standard parts in boldface.

Performance Data

Electrical
Insulation resistance.
$\geq 5 \times 10^{4}$ megohms min. between contacts

Dielectric withstanding voltage:
500 volts AC. rms. 60 Hz at sea level

Current rating:
2 amps max terminated to 610 grams/meter², 1.57mm (2 oz./ft², 0.062") wide copper cable laminated between 0.08mm (0.003") thick polyester insulation material

Mechanical
Insertion force.
500 grams per contact when mated to 0.64mm (0.025") square tin-lead plated pins

Average insertion force:
400 grams per contact when mated to 0.64mm (0.025") square tin-lead plated pins

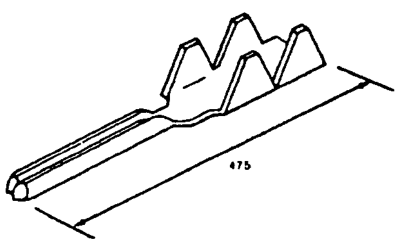
Minimum withdrawal force:
30 grams per contact when unmated from 0.64mm (0.025") square tin-lead plated pins

Average withdrawal force:
50 grams per contact when unmated from 0.64mm (0.025") square tin-lead plated pins

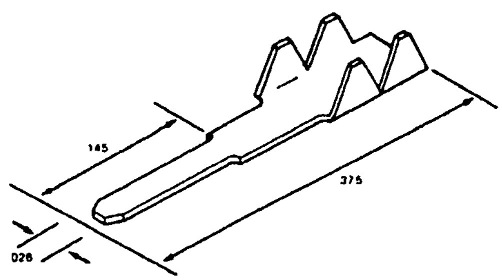
9.3 Pin Contacts and Solder Tabs
Pin contacts and solder tabs offer a gas-tight termination between flextail and contacts.

In this method the keyboard is supplied with a flextail of specific length. Crimped to the flextail(s) is a non-shrouded connector of either individual pins or solder tabs.

Pin Contact

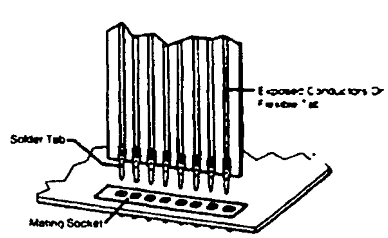


Solder Tab



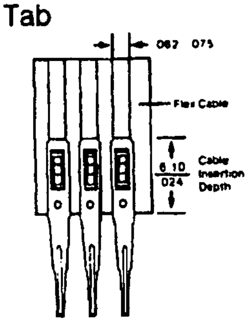
After the pin contacts are crimped, they are inserted into receptacle sockets that have been soldered to the contact points of the printed circuit board.

Solder Tabs



Crimping pierces through both sides of the flextail, allowing any of the circuit designs discussed in Chapter 2 to be used.

Berg Solder Tab

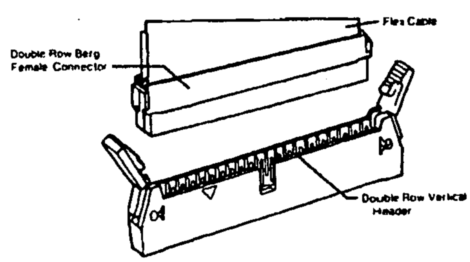


The cost of this interface depends on the contact plating material (tin/lead or gold) and number of positions required.

9.4 Double Row Connectors
Double row connectors are mainly used when the number of flextail leads exceeds the space required for a single straight row connector type.

When used with a membrane keyboard, double row connectors require that the keyboard have two separate flextails, one above the other. These flextails must crimp a single straight row connector on each tail. The Berg Clincher 65801 is the most commonly used connector for this application. These two connectors then fit into a single double row header that has been soldered to the printed circuit board.

Berg Double Row Connector



Keyboards that use a printed circuit board as the lower circuit can accommodate a double row pin connector soldered directly into the keyboard.

The cost of this interface depends on the contact plating material and number of positions required.

Many companies manufacture double connectors and most of them work to standard specifications.

Chapter 10 Non-Conductive Substrate Materials

Non-conductive material can be used either as the electrical circuit substrate or as a separate dielectric layer. This chapter discusses several types of non-conductive insulating carriers:

- Polycarbonate
- Polyester
- Glass epoxy
- Polypropylene
- High-temperature plastic

Each of these materials has its advantages and the selection should be based on the requirements of the intended application.

10.1 Polycarbonate as a Substrate Material
Polycarbonate film serves as an effective non-conductive substrate, particularly as manufacturers identify and correct some of its previous shortcomings.

A non-conductive substrate must remain dimensionally stable during manufacturing and actual use to ensure uninterrupted circuit routing. Under both dry and humid conditions, shrinkage rates of polycarbonate at 75°C to 175°C are less than one percent. Moreover, exposure to dry heat at 125°C for six months indicated no increase in brittleness or cracking.

In addition, it remains malleable (i.e., does not crack) when folded, minimizing the risk of damage to the printed conductor inside a 180° folded membrane circuit. (Refer to the fold test described in Section 11.1.7.) Polycarbonate film in association with recommended conductive inks has excellent adhesion qualities.

Tests were conducted with 5 mil. polycarbonate film where the circuit routing had been printed with DuPont 5007 silver ink. The film was then folded and pressed with a 15 pound bar. Circuit resistivity increased only 12% at room temperature and an additional 3% when the folded circuit was heat sealed for four or five seconds at 350°F. (Refer to Section 11.1 for further discussion of polycarbonate dimensional stability.)

An important consideration of a material's dielectric strength is its ability to withstand electro-static discharge that could otherwise damage internal electronic components. Building up successive layers of polycarbonate material in membrane keyboard construction can result in passive E.S.D. protection of 20KV or more. (Refer to Section 8.1.)

The dielectric strength of four mil. polycarbonate film is 1400 volts/mil. at 25°C and volume resistivity of 1×10^{16} ohms/centimeters at 25°C. The dielectric constant of polycarbonate film does not change from −25°C to 142°C.

Polycarbonate film is easily processed and die cut, yet its tensile yield strength is 8,400-8,800 psi (ASTM D882 with 4 mil.) and its tear strength is 1,150 to 1,570 psi (ASTM-49T with 4 mil.).

Polycarbonate's overall tensile modulus averages 290,000 psi at 25°C.

Note
Tensile modulus is an expression of the ratio between a deforming force and the corresponding fractional deformation caused by the force.

No outgassing of polycarbonate film has been reported following tests conducted at 1×10^{7} mm Hg at 100°C.

Polycarbonate has a recommended list of conductive inks that have been approved for material compatibility.

10.2 Polyester as a Substrate Material
Polyester possesses many characteristics which make it an ideal non-conductive substrate:

- Resistance to abrasion and chemicals
- Reasonable dimensional stability
- High tensile modulus

Because of these qualities, polyester has gained a broad acceptance among membrane keyboard manufacturers as a conductive routing substrate.

As described in Section 1.1 and 1.2, the upper circuit of a membrane keyboard flexes through openings cut in the spacer layer in order to make contact with the lower circuit. The total travel of the upper circuit is typically 0.008" for non-tactile and .028" for tactile. With a tensile modulus of 500,000 psi at 25°C, polyester ensures in excess of ten million operations.

The dimensional stability of polyester depends on temperature. Thermal shrinkage of a five mil. polyester film at 100°C is approximately 0.5%, which is acceptable for most applications. Thermal shrinkage increases to approximately 2% at 175°C.

Although generally acceptable, this additional shrinkage can become critical if the graphic overlay is polycarbonate while the underlying circuit layers are polyester. Under certain conditions, the polyester layer can shrink out of register, impeding switch actuation with the polycarbonate touch panel. This potential problem may be dealt with when initially designing the keyboard by providing a sufficient margin in keypad location on the graphic overlay.

The resistance of polyester to abrasion and chemical damage is excellent. (Refer to Section 11.1 for more information.)

The dielectric properties of polyester are also outstanding. The breakdown voltage from an electro-static discharge of five mil. is 18,500 volts at 60 Hz or 2,700 volts/mil. at 23°C.

Building up successive layers of polyester material in membrane keyboard construction can result in passive E.S.D. protection of 20KV or more.

No outgassing of polyester film has been reported following tests conducted at 1×10^7 mm Hg at 100°C.

Like polycarbonate, polyester has a recommended list of conductive inks that have been approved for material compatibility.

10.3 Glass Epoxy
Glass epoxy non-conductive substrates are used as the base for the construction of printed circuit boards. The PCB is used as a rigid lower circuit for membrane and metal dome keyboard construction. The thickness is typically 0.032", 0.062", or 0.093".

PCBs conductive routing is generally copper deposited through electrolysis and then tin/lead reflow plated. The circuit routing is typically on both sides of the PCB, simplifying the layout and concentration of the routing. Additional daughter boards and PCBs may be stacked together for more complex circuitry and electronics. Gold through hole plating of contact points is an optional conductor for keyboards that require high performance or operate in a harsh environment.

The standard glass epoxy material is F.R.4 rated (fire retardent #4 specification).

Should any additional electronics require assembly to the PCB during keyboard manufacture, a solder mask may be specified that coats and protects the exposed circuitry from damage during assembly.

10.4 Polypropylene
Polypropylene is primarily used in switch technology as a dielectric insulator. Common applications involve the placement of two to three mil. films over the top circuit layer of a flexible membrane switch as a conductive dielectric insulator.

Polypropylene has the following properties:

Volt resistivity ohms/cm: 1×10^{18}
Tensile modulus rating: 240,000 psi
Leading strength: 3,000-4,000 volts/mil.

Chapter 11
Graphic
Overlay Materials

As the outermost layer of a membrane keyboard, the appearance of a graphic overlay is primarily responsible for the operator's overall impression of the keyboard.

Functionally, the graphic overlay identifies keypad location, accommodates a logo, and provides window display zones for status information about the equipment.

Currently, polyester and polycarbonate plastic films are the preferred graphic overlay materials. Film selection depends on the specific requirements of the application.

11.1 Polycarbonate as a Graphic Material
A variety of companies manufacture polycarbonate plastic films. The largest supplier is currently General Electric Company, which markets their product under the tradename Lexan. These films have several advantages:

- Optical clarity
- Dimensional stability when heated
- Malleability

In addition, they may be used with a wide variety of recommended printing inks.

These advantages are offset by the fact that polycarbonate film offers only moderate resistance to abrasion and chemicals. Although this weakness can be minimized by adding surface hardcoats, this step often equals the cost of the polycarbonate material itself. (Refer to Hardcoat Characteristics Chart.)

Polycarbonate Film

Product Availability:

Type	Thickness
Gloss	.003"-.030"
Matte	.005"-.030"
Fine Velvet Texture	.005"-.020"
Medium Coarse Suede Texture	.010"-.020"
Hardcoat One Side	.010"-.030"

Benefits:

Haze Free Clarity
Allow true colors.

Heat Resistance
Permits high temperature applications up to 270°F in close proximity to illuminating sources

Cold Resistance
Ductile below - 40°F

Chemical Resistance
Good only to non-aromatic chemicals

Dimensional Stability
Maintained at elevated temperatures

Toughness
High tear strength

Surfaces
Different textures are available

Scratch Resistance:

Suede Excellent
Velvet Very Good
Gloss Fair to Poor
Matte Fair to Poor
Hardcoat Excellent

11.1.1 Surface Textures
Lexan can be manufactured with several surface textures:

- Gloss
- Matte
- Fine velvet
- Medium suede
- Coarse suede

The fine velvet and suedes offer superior abrasion resistance and may not require added hardcoating.

11.1.2 Embossing
Polycarbonate material reacts well to embossing due to its deformation stability at the elevated temperatures required to emboss. Polycarbonate also demonstrates exceptional ability to hold a formed shape (Refer to Section 13.1.)

11.1.3 Chemical Resistance
Polycarbonate resists a variety of dilute acid solutions, most foods (e.g., fruit juice, tea, coffee), as well as normal cleaning agents.

However, polycarbonate films without a hardcoat are moderately attacked by chlorinated and aromatic hydrocarbons, such as benzene, toluene, ketones, and esters. If the anticipated environment contains such chemicals, either additional surface hardcoating or a polyester graphic overlay is recommended. The following tables contain specific information about polycarbonate chemical resistance.

Chemical Resistance Chart

Polycarbonate (Non-Hardcoat)
Exposure: Immersed 6 days
N = No Effect S = Soluble A = Chemically Attacked

Chemical	Effect	Chemical	Effect
Bacon Fat	N (80°C)	Methyl Salicylate	S
Beer	N	Milk	N
Catsup	N	Mustard	N
Citric Acid 5%	N	Oleic Acid	N (80°C)
Cocoa	N (80°C)	Orange Juice	N
Cod Liver Oil	N	Permanent Ink	N
Coffee	N	Pine Oil	N
Grape Juice	N	Sardine Oil	N (80°C)
Iodine	N	Shortening	N (80°C)
Isopropanol 70%	N	Tea	N (80°C)
Kerosene	N	Tomato Juice	N
Lemon Juice	N	Vicks' Vaporub	N
Mayonnaise	N	Wine	N
Merthiolate	N	Wine Vinegar	N
		Whiskey	N

Exposure. Immersed one month

Chemical	Effect	Chemical	Effect
Acetic Acid. 5%	N	Light Lube Oil	N (80°C)
Detergent		Soap Solution, 5%	N
Solution. 2%	N	Oleo	N (80°C)
Freon 22 (Bomb)	S	Ozone, 1%	A
Hydrogen		Soya Oil	N (80°C)
Peroxide. 30%	N		

Note:
Amines, alkalies and ammonia will attach polycarbonate film as well as chlorinated hydrocarbons, aromatic hydrocarbons and ketones. Polycarbonate offers very good solvent resistance to oil, alcohol and aliphatic hydrocarbons. Chemical resistant coating is available.

Hardcoat Characteristics Chart

Chemical and abrasion resistant surface

Optical

Property	Test Method	Units	Typical Value
Light Transmission	ASTM D1003	%	≥ 90
Haze	ASTM D1003	%	≤ 0.7
Gloss	ASTM D523		
60° Backpainted, Flat Black			95
60° Unpainted, Clear			160
85° Backpainted, Flat Black			80
85° Unpainted, Clear			90

Abrasion

Property	Test Method	Unit	Typical Value
Taber Abrasion	ASTM D1044	Change	
500 gram load		in %	
CS-10F wheel		haze	
10 cycles			+ 1.2
25 cycles			+ 1.3
50 cycles			+ 2.0
100 cycles			+ 6.3
300 cycles			+ 14.3

Chemical Resistance

Solvents	Test Method	Effect on Coating
Heptane	1 hour	None
Ethyl, Isopropyl alcohol	continuous	None
Dichloromethane	"wet" contact	Partially dissolved
Carbon tetrachloride	@72°F	None
Acetone, Methyl ethyl ketone		None
Butyl Cellosolve		None
n-Butyl acetate		Slightly pitted
Toluene		Slightly pitted
40% Sodium hydroxide		None
Conc. Hydrochloric acid		None
Amoco diesel fuel		None
Amoco unleaded premium		None
Gunk S-C degreaser		None
Turpentine		None
VM & P naphtha		None

11.1.4 Optical Clarity

The optical clarity of polycarbonate surpasses that of polyester.
Lexan 1.2 mil. clear film has light transmission values of 91% with 0% haze at wavelengths from 400 mu to 1,000 mu. Due to its non-crystaline molecular structure, as polycarbonate film thickness increases to 10 mil., its light transmission decreases to 90% while haze, or image blurring, increases to just 0.5%.

This distortion-free quality allows for use of subsurface color printing onto the graphic overlay without risk of color or image distortion.

Polycarbonate transparent membranes have an anti-glare hardcoat which is also mar and chemical resistant. (Refer to Section 11.1.8.)

11.1.5 Tensile Strength

Polycarbonate film is easily processed and die cut, yet its tensile yield strength is 8,400-8,800 psi (ASTM D882 with 4 mil.) and its tear strength is 1,150 to 1,520 psi (ASTM-49T with 4 mil.). (Refer to Polycarbonate Film Properties Chart.)

Polycarbonate's overall tensile modulus averages 290,000 psi at 25°C.

Note
Tensile modulus is an expression of the ratio between a deforming force per unit area and the corresponding fractional deformation caused by the force.

Polycarbonate Film Properties

Physical Properties

ASTM Method	Property	Units	Value
D1505	Specific Gravity		1.20
D774-46	Bursting strength	Mullen Pts.	25-35
D643-43	Folding Endurance		Survives 250–400 Folds
D570	Water absorption	%	.35
D882, 638	Tensile yield strength		
	F(°C)	psi	
	77 (25)		8400–8800
	167 (75)		7000
	257 (125)		4500
D882, 638	Tensile Modulus		
	77 (25)		290,000–300,000
	167 (75)		270,000
	257 (125)		215,000
D882, 638	Ultimate tensile strength		
	77 (25)		8,600–9,300
D882, 638	Elongation	%	
	77 (25)		85–105
	257 (125)		120
D1004-49T	Tear strength initiation	lb/in	1150–1520
D1922 (Elmendorf)	Tear strength propogation	lb/in	44–55

Thermal Properties

ASTM Method	Property	Units	Value
D648	Flexural deflection at		
	264 psi	°F (°C)	275 (135)
	66 psi		285 (140)
D1637	Tensile heat distortion at		
	50 psi	°F (°C)	302 (150)
D696	Coefficient of linear expansion between:		
	−30°C and 30°C	in/in/°C	6.75×10^{-5}
	−22°F and 86°F	in/in1/2°F	3.75×10^{-5}
D759	Resistance to cold	°F (°C)	−150(−101)
C351	Specific heat	Btu/lb °F	.30
D746	Brittleness temperature	°F (°C)	−211(−135)
	Flammability (UL Bulletin 94) 20 MIL		V-2

Electrical Properties

ASTM Method	Property	Units	Value
D150	Dielectic constant (4mil) (−13° to 288°F)		
	60Hz		2.99
	10^3		2.99
	10^6		2.93
	Power Factor (4 mil)		
	60H	%	0.10–0.23
	10^3		0.13
	10^6		1.10
D149	Dielectic strength (4 mil)	Volts/mil	
	77°F (water)		1400
	122°F (oil)		1830
	212°F (oil)		1835
D257	Volume Resistivity	Ohm-cm	10^{16}

11.1.6 Thermal Shrinkage

Unlike polyester, polycarbonate is malleable and yet demonstrates little functional deformation due to temperature.

Thermal shrinkage at 175°C is less than 1%. In addition, exposure to dry heat at 125°C for six months indicated no increase in brittleness or cracking.

This lack of shrinkage is noteworthy since many manufacturing techniques require elevated temperatures. Once the material returns to room temperature, irregularities and shrinkage must be kept to a minimum. Flame retardant polycarbonate is also available. (Refer to Section 11.1.9)

11.1.7 Fold Testing

Polycarbonate film exceeds a 180° fold test of 400 cycles (ASTM D643-43), an important consideration in membrane folded circuits. Most keyboard designs are specified for a minimum of one million to a maximum of ten million operations. (An operation consists of one switch closing and then opening.) Both polycarbonate and polyester meet this requirement.

Abrasion Resistance (Reported as a percent of transmitted light scattered, i.e. haze.)

Taber Abrasion Test ASTM D-1044	%	%
500 Gram Weight		
Start	2.0	2.0
10 cycles	2.2	7.5
25 cycles	2.5	16.3
50 cycles	2.63	18.5
75 cycles	4.75	18.7
100 cycles	4.96	21.5

Chemical Resistance ASTM D-1308	(Time until visual attack)	
10% Sodium Hydroxide	>36 hrs.	>16 hrs.
40% Sulfuric Acid	>36 hrs.	< 8 hrs
Gasoline	>36 hrs.	>16 hrs.
Benzene	>36 hrs.	<60 sec.
Acetone	>36 hrs.	<60 sec.
Methylene Chloride	>36 hrs.	< 8 hrs.
Ethylene Dichloride	>36 hrs.	>16 hrs.
Carbon Tetrachloride	>36 hrs.	>16 hrs.
Methyl Alcohol	>36 hrs.	>16 hrs.

11.1.9 Flame Retardant Polycarbonate

In an application where fire prevention is of great concern or in an extremely hostile environment, a flame retardant polycarbonate may be specified which is UL listed for flammability. The following chart illustrates the properties of this film.

Description:
Flame-retardant polycarbonate film, available from .015" to .030" thick, UL rated 94V-0.

Properties

Optical

Property	Test Method	Units	Typical Value
Light transmission	ASTM D1003	%	85
% Haze	ASTM D1003	%	1

Mechanical

Property	Test Method	Units	Typical Value
Specific gravity	ASTM D792		1.32
Water absorption	ASTM D570	%	0.28
Tensile strength			
Yield	ASTM D882	psi	10.000
Break	ASTM D882	psi	8.800
Elongation	ASTM D882	%	25-50
Tensile Modulus	ASTM D882	psi	320.000
Tear Strength			
Initiation	ASTM D1004	lb/in	1700-2000
Propagation	ASTM D1922	lb/in	73-82(.015" film)
Impact Strength	Gardner	in—lb	60(.030" film)

Thermal

Property	Test Method	Units	Typical Value
Tensile Heat Distortion @50 psi	ASTM D1637	°F (°C)	302 (150)
Flexural Deflection @264 psi	ASTM D648	°F (°C)	275 (135)

Electrical

Property	Test Method	Units	Typical Value
Dielectric Strength	ASTM D149	volts/mil	1520(.015" film)
Dielectric Constant	ASTM D150		
60 Hz			2.9
10^3 Hz			2.8
10^6 Hz			2.8
Dissipation Factor	ASTM D150	%	
60 Hz			0.26
10^3 Hz			0.28
10^6 Hz			1.17
Volume Resistivity	ASTM D257	ohm-cm	10^{16}

Flammability

Property	Test Method	Units	Typical Value
UL Flammability	Bulletin 94		V-0 @ .015"
Oxygen Index	ASTM D2863	%	33
Horizontal Burn	ASTM D635		
AEB		in	1.4
ATB		sec	5
FAA Flammability	FAR 25.853		pass
Smoke Density	ASTM E662/	D(4 min)	6
(Flaming)	NFPA 258	D(max)	36

Chemical Resistance

Household Liquids	Test Method	Effect on Coating
Strong Tea	24 hours	None
Black Coffee	@ 80°F,	None
Catsup	80% R.H.	None
Mustard		None
Vegetable dye		None
Vinegar		None
Lemon juice		None
Tomato juice		None
Grape juice		None
Milk		None
CLOROX™		None
WISK™		None
FANTASTIC™		None

Other Properties

Property	Test Method	Units	Typical Value
Tensile Strength	ASTM D882	psi	
Yield			9,400
Break			10,200
Elongation	ASTM D882	%	85-105
Tear Strength	ASTM D1922	lb/in	44-55
Resistance to humidity	GE Test (720 hrs. @ 100°F, 100% RH)	—	No blistering No visual change
Heat Aging	GE Test (168 hrs. @ 160°F)	—	No blistering No visual change

Graphic Overlay Materials

11.2 Polyester as a Graphic Material
A variety of companies manufacture polyester plastic films. The largest supplier is currently E.I. DuPont DeNemours & Company, which markets their product under the tradename Mylar. These films have several advantages:

- Cost
- Durability
- Resistance to abrasion

However, polyester lacks the optical clarity at thicknesses frequently required in graphic overlays.

11.2.1 Surface Textures
Mylar can be manufactured in either gloss or matte light-reflective textures. Unlike polycarbonate, standard textures are not available except by photo-active U.V. texturing. This process requires pretreatment of the polyester material and adds an additional cost to the final product.

11.2.2 Embossing
Polyester does not react well to embossing or thermoforming because significant dimensional instability begins to appear at the high temperatures required to emboss. (At temperatures above 160°C, polyester is subject to shrinkage and warping and melts at 250°C.) Polyester may be embossed using male/female hard tooling. This additional tooling does add to the cost of the product.

11.2.3 Optical Clarity
Unlike polycarbonate, polyester has a crystalline molecular structure. This structure ensures durability, but interferes with optical clarity by diffusing light as it passes through the material.

A typical graphic overlay thickness of 7.5 mil. demonstrates transmission levels of 85% and a 1.5% haze. These values indicate a somewhat weak image definition and color rendition. Ten mil. polyester proves unacceptable as a graphic overlay due to increased haze and poor light transmission.

11.2.4 Tensile Strength
Polyester's overall tensile modulus averages 500,000 psi at 25°C.

Note
Tensile modulus is an expression of the ratio between a deforming force per unit area and the corresponding fractional deformation caused by the force.

A 1 mil. film exceeds the ASTM-MIT fold endurance test by compiling over 100,000 180° cycles. However, polyester does demonstrate increased current resistivity in a folded circuit.

The dimensional stability of polyester depends on temperature. Thermal shrinkage of a five mil. polyester film at 100°C is approximately 0.5%, which is acceptable for most applications. Thermal shrinkage increases to approximately 2% at 175°C.

11.2.5 Chemical Resistance
As noted by its exceptional tensile modulus, polyester shows unusual durability. Its major advantage over polycarbonate is its superior resistance to chemicals, particularly hydrocarbon-based chemicals. (Refer to Polyester Chemical Resistance Chart.)

Polyester Chemical Resistance

Chemical	Effect
Alcohol	N
Cooked Beets	N
Liquid Bleach	N
Cooked Carrots	N
Catsup	N
Cherries (liquid maraschino)	N
China Marker	S*
Cocoa	N
Coffee	N
Cola	N
Cranberry Sauce	N
Crayon	S**
Detergent (50% solution)	N
Dishwashing Liquid	N
Ethyl Acetate	N
Ferrite Chloride	N
Grape Juice	N
Hand Lotion	N
Iodine	N
Lemon Juice	N
Lighter Fluid	N
Machine Oil	N
Maple Syrup	N
Mayonnaise	N
Merchurochrome	N
Merthiolate	N
Milk	N
Mustard	N
Nail Polish	S**
Nail Polish Remover	N
Oleomargarine	N
Orange Juice	N
Pencil	S***
Rubber Cement	N
Cooked Spinach	N
Tea	N
Tomato Juice	N
Food Color	S****
Vegetable Oil	N
Vinegar	N
Worcestershire Sauce	N

16 hours at room temperature then washed with water.

N = No Effect
S = Stain
* - No stain after washed with alcohol
** - No stain after washed with nail polish remover
*** - Slight mark after washed with soap and water
**** - Slight mark after washed with nail polish remover

11.2.6 Durability
Polyester's crystaline structure gives the material superior abrasion resistance when compared to polycarbonate. Most keyboard designs are specified for a minimum of one million to a maximum of ten million operations. (An operation consists of one switch closing and then opening.) Both polycarbonate and polyester meet this requirement.

Polyester Film

Physical and Thermal Properties

Physical Properties at 23°C and 50% RH

Property	Typical Value 1 mil film	Unit Measure	Test Method
Ultimate Tensile Strength (MD)	25,000	psi	ASTM D882-64T
Stress to produce 5% Elongation	15,000	psi	Method A (100% elongation per minute)
Ultimate Elongation (MD)	120	%	
Tensile Modulus (MD)	550,000	psi	
Impact Strength	6.0	kg-cm/mil	DuPont Pneumatic Impact Tester
Folding Endurance	100,000	cycles	ASTM D2176-63T (1 kg loading)
Tear Strength—propagating (Elmendorf)	20	grams/mil	ASTM D1922-61T
Tear Strength—initial (Graves)	800	grams/mil	ASTM D1004-66
Tear Strength—initial (Graves)	1,800	lbs./inch	ASTM D1004-66
Bursting Strength	66	psi	ASTM D774-63T
Density	1.395	grams/cc	ASTM D1505-63T
Coefficient of Friction—Kinetic (film-to-film)	.45	—	ASTM D1894-63
Deformation Under Load	0.11	%	ASTM D621-64 Method A 500 lb. load

Thermal			
Melting Point	250°C		Fisher-Johns
Zero Strength Temp.	248°C		DuPont Test*
**Penetration Temp.	230°C;270°C		ASTM D876-65
Coefficient of Thermal Expansion (30°C-50°C)	1.7×10^{-5}	inch/inch/°C	Modified ASTM D696-44
Coefficient of Thermal Conductivity (1000 "Mylar" A at 25 to 75°C)	1.05	(BTU)(inch)/(ft²)(hr)(°F)	
	3.7×10^{-4}	(cal)(cm)/(cm²)(sec)(°C)	
Specific Heat (25°C)	.28	cal/gm/°C	
Heat Sealability	No		
Flammability	Slow to self extinguishing		

*The temperature at which a single sheet of film over a ½" diameter heated rod supports a tensile load of 20 psi for 5 seconds.
**1000gm. weight on ¹⁄₁₆" dia. ball, 0.5°C/min. rise rate; second value at 35°C/min. rise rate.

11.3 Selective Texturing

The surface coating or texturing of selected areas of a polyester or polycarbonate graphic overlay is rapidly gaining popularity. Surface texturing can enhance a graphic overlay in several respects:

- Protect the overlay from a variety of chemicals
- Harden the overlay against abrasion
- Reduce glare from window and display zones
- Define functional areas on the overlay

These considerations are of particular importance when selecting a polycarbonate material for a keyboard that may be subjected to a harsh environment. Chemical resistance to solutions of 5% hydrochloric acid and aromatic hydrocarbons may be obtained with selected photo-active U.V. surface coating.

Polyester and polycarbonate can be textured in four general degrees of coarseness: gloss, matte, velvet, and suede.

Polyester is normally resistant to abrasion and chemicals without U.V. surface texturing. It requires pretreatment if it is to be surface textured. For these reasons, it is less often surface textured.

Selective texturing involves screen printing a photosensitive compound over the surface of the graphic overlay where texturing is desired. Areas such as window display zones which are to remain untextured should not be coated. The coated overlay is then passed through a curing chamber of nitrogen gas and high intensity ultra-violet light. The final qualities of the coating depend on the concentration of nitrogen gas, the intensity of the ultra-violet light, and the length of exposure to the ultra-violet light.

Selective texturing can also be used for individual key identifications by applying a texture to either the keypads or the backgrounds.

Chapter 12
Color Matching Systems

The colored inks that are printed on the graphic overlay must be carefully selected and manufactured. In particular, you should note the ambient light source when specifying color to the keyboard manufacturer.

Basically, there are three types of light sources:

1 Daylight
2 Incandescent light
3 Flourescent light

Since all the graphic printing takes place on the sub-surface or rear side of the exposed surface of the graphic overlay, you must also consider the gloss level desired on the front of the overlay. You can specify this level as a quantitative value, or in terms of matte, low luster, or high gloss.

This chapter briefly discusses four color matching systems:

1 Pantone Matching System
2 Federal Standard Series 595
3 Munsel
4 Customer-supplied color chips

12.1 Pantone Matching System
The Pantone Matching System, sometimes abbreviated to P.M.S., is the most commonly used means of color matching.

This system evolved from the offset printing trade and, consequently, the color swatches represent the appearance of the colors on paper, not sub-surface printing on plastic.

When specifying a high-gloss level refer to the C section of the color wheel; for matte or low-luster gloss, use the U section.

Note
Due to their production process, the color wheels sometimes vary from book to book.

12.2 Federal Standard Series 595
This series represents an improvement in consistency, opacity, and gloss levels over P.M.S.

An enamel-baked process is used to produce the color chips in this series, lending them their high consistency and opacity.

In contrast to the two levels of P.M.S., the Federal Standard Series consists of three levels of gloss rating:

1 Gloss
2 Low luster
3 Lusterless

This color matching system was designed for use by the spray paint finishing industry. For this reason, the Federal Standard Series should be selected when matching graphic keyboard colors to sprayed housing finishes

12.3 Munsel
Unlike other color systems, the Munsel system does not equate color to any fixed formula of paint or ink pigmentation. Rather, it plots color on a three-dimensional scale.

The coordinance scale which the colors are based on is known as the Hunter L.A.B Scale It has become the standard for high-quality color definition.

A coordinance plot is calculated for specific colors by assigning a numeric value for the chroma, hue, and intensity. Because these values are quantifiable, the system can utilize computers to aid in analysis.

12.4 Customer-Supplied Color Chips
Occasionally, a keyboard manufacturer is requested to match the overlay colors to a set of customer-supplied chips. These chips are typically either standard corporate color chips or a color that appears on equipment which will be in proximity to the keyboard.

As mentioned at the opening of this chapter, you should supply the manufacturer with the ambient light source, surface textures, and gloss levels

12.5 Spectrometer Measurement
Computer-aided analysis provides the best method of ensuring consistent color matching.

A customer first selects a color from one of the color matching systems or provides a color chip. A computer-aided photospectrometer then determines a quantitative value of the customer-selected color That selected color now becomes the "standard" against which the keyboard manufacturer prepares the graphic ink pigments.

These ink pigments are then combined and the resultant ink is test printed and analyzed by the photospectrometer. The determined values of the test run printing and the customer-specified color are compared on a three-dimensional graph for accuracy. This comparison also considers ambient light, graphic overlay material and gloss levels. Using the Hunter L.A.B. scale as a constant, a value of 0.4 ($\pm$ 0.2) at all coordinance points is considered a match. Any color difference of 0.4 or less compared to the customer standard is undetectable to the naked eye.

Chapter 13
Key Identification

In addition to the use of graphics and color, there are three methods for identifying keypad location on a graphic overlay:

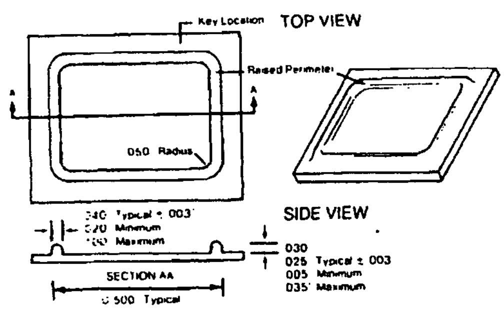
1 Embossing
2 Bezels
3 Selective texture

13.1 Embossing

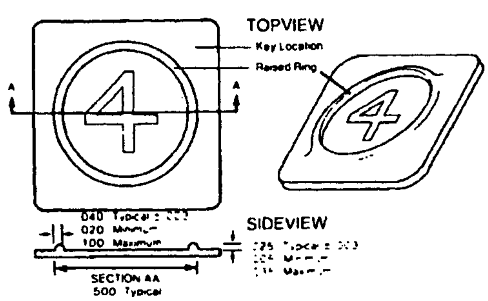
Embossing proves to be a versatile technique since a variety of configurations can be created, including raised circles, squares, or rectangles. In addition, no danger of dirt buildup exists since the embossing is formed from the graphic overlay and not by adding separate layers with cut outs at keypads over the graphic.

For flat non-tactile membrane keyboards, an embossed raised perimeter or ring key-pad boarder can be added to provide positive keypad location.

Embossed Raised Perimeter Rectangular Key

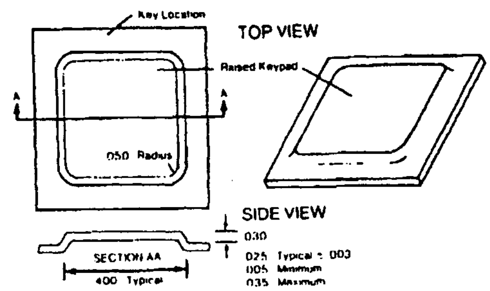


Embossed Raised Perimeter Ring Keypad



For tactile membrane and tactile metal dome/PCB keyboards without an acutator layer, each keypad on the graphic overlay is embossed in a raised configuration to protect the upper circuit from surface tension caused by the graphic overlay which may preload and partially close the underlying switch.

Embossed Raised Square Key



The embossing process itself involves using a heated match mold tool to raise a keypad or border on a graphic overlay. The maximum height is 0.035" above the overlay surface.

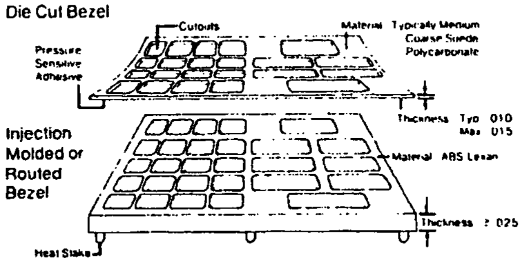
Note
A matched male/female die increases the tooling cost.

When using embossing to accent a key location, it is important to specify the detail of the embossing design. Although both polycarbonate and polyester can be embossed, polycarbonate forms more readily and requires less expensive tooling than polyester. These advantages are due to its lower thermal forming temperature.

13.2 Bezels
Keyboard bezels typically take one of two forms:
1 Surface Bezel
2 Perimeter bezel

13.2.1 Surface Bezels
A surface bezel consists typically of a 10 mil. polyester or polycarbonate film with die cut openings at each keypad location. In this way, the surface bezel provides a means of tactile location for the keypads. Additionaly, the feel of the surface bezel can be enhanced by texturing.

Bezel Types



A surface bezel can also be an injection-molded or routed frame with openings at keypad locations. An injection-molded surface bezel would require more expensive tooling than a die-cut film surface bezel.

Note
A surface bezel increases the risk of dirt becoming trapped at the edges of the keypads.

13.2.2 Perimeter Bezels
Although perimeter bezels do not typically define key location they may be used to secure and define functional areas on a keyboard. The perimeter bezel consists of an injection-molded plastic frame which mounts around the outer edge of the keyboard. The bezel seals the otherwise exposed edges of the keyboard's laminated layers from peeling, dust, and chemical spills. In addition, it allows for easy one piece surface mounting of the entire keyboard assembly.

Enhanced protection from electro-static discharge is also provided by a perimeter bezel in two ways:

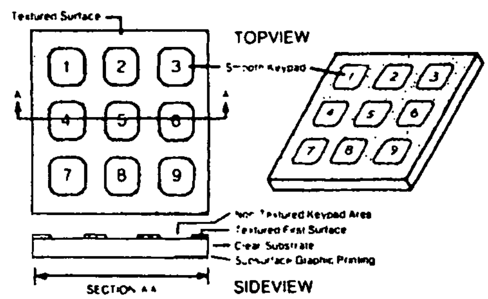
1 Passive E.S.D. protection by use of a non-conductive injection-molded bezel which mechanically seals the exposed edges of the keyboard to points of entry from E.S.D. flashover.

2 Active E.S.D. protection by the use of a conductive, independently grounded perimeter bezel which effectively bypasses the internal circuitry. (Refer to Section 8.2.)

A perimeter bezel is usually heat staked to the keyboard.

13.3 Surface Texturing
Surface texturing of the graphic overlay material can be used to identify a keypad or group of keys which perform similar functions. This texturing involves the use of a photosensitive coating and ultra-violet light. (The process is described in Section 11.3.)

Selective Texture Keys



Note
Surface texturing of a graphic overlay does not interrupt the overlay surface. Dirt does not become trapped at the keypad edges.

Chapter 14
Keytops and Actuators

14.1 Keytops and Actuators
Floating or hinge keytops can be assembled over a tactile membrane switch or over a metal dome switch. Choice of dome type depends on cost, life expectancy, and touch requirements. An actuator tip must be designed as an integral part of the key. The actuator is always applied to the center of the dome.

14.1.1 Metal Dome Actuators
All metal dome constructions require a pointed actuator with a rounded bottom that corresponds to a depression on the center of the metal dome itself. This actuator would be designed on both a separate or hinged key. Refer to Section 1.5.

14.1.2 Tactile Membrane Actuators
For tactile membrane switches, the actuator can have two distinct shapes. For living hinge keytop designs, the actuator is D-shaped with a flat bottom. For separate floating keytops, the actuator is round with a flat bottom. Refer to Section 1.8.

14.1.3 Keytop Design
Keytops can be standard or custom low profile designs with texture or sculpture. Height of the keytop depends upon customer requirements.

For full travel membrane keyboards, the keytop is commonly specified to meet DIN standards for ergonomic design.

14.1.4 Floating Keytops
Floating plastic keys are assembled over membrane or metal dome switches. The keys are stationed in place by means of a bezel or frame positioned over the switch layer. In the keytop design, the actuator must be integral to the key itself. Refer to Section 1.6.

14.1.5 Living Hinge Keytop
Living hinge keytops consist of a single frame of keys with actuators that mount over a switch layer. The keytops are attached to the frame by a thin plastic tab that acts as a hinge, allowing the key to flex.

The shape of the actuator, which is an integral part of the keytop, depends upon whether a tactile membrane or metal dome switch is specified. Dome choice depends on tooling cost, travel, force, feel, and life expectancy requirements. Refer to Section 1.8

Chapter 15
Display Zones

This chapter discusses three construction techniques used when incorporating a window display zone on the keyboard:

- Dyed-inset window filters
- Screen-printed window filters
- Dyed-underlaminate window filters

15.1 Dyed-Inset Window Filter

A dyed-inset window filter enhances the apparent brightness of electronic displays such as seven-segment displays.

The dyed-inset window filter allows the majority of those light wavelengths emitted by the display to pass through the filter while filtering out ambient light wavelengths, thus increasing the display's apparent brightness and contrast.

15.1.1 Manufacturing Process

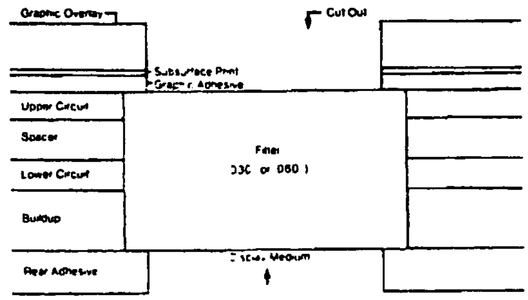
The filter is produced by dying a clear plastic film (typically polycarbonate) to within close values of the spectrophotometric and transmission curve of the electronic display.

Note
This process tends to hold closer tolerances than screen-printed filters.

15.1.2 Materials

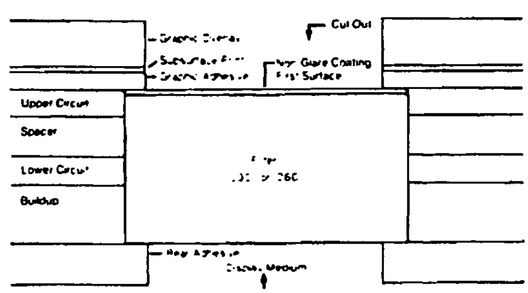
The filter window typically consists of a precision-dyed 0.030" to 0.060" rigid plastic that is mounted beneath a cutout in the graphic overlay.

Inset Window Filter



The electronic display is located on the inner surface or behind a cutout on a rigid PCB. Corresponding cutouts in the switch and build-up layers allow the electronic display to be viewed from the front of the keyboard. Use of laminated acrylic adhesives throughout the keyboard construction is recommended to ensure an environmentally sealed design. In addition, a non-glare, chemical and abrasion resistant coating can be applied over the entire exposed window surface for added protection

Non-Glare Inset Window Filter



Note
A proper inset window filter design can withstand a high-pressure water test without compromising switch performance.

High-strength adhesives must be used in these cases.

15.1.3 Specification Considerations

The total available circuit routing area of the keyboard affects the window filter specification. Early in the design process, you must ensure that circuitry and window filter locations will not interfere with each other. Although electronic displays are frequently located at the corners of a keyboard, the accompanying window filter cutouts must not force circuit routing too close to the perimeter. (Sections 3.1, 3.2, and 8.1 discuss this topic.)

Display Zones

For product specifications refer to the following chart:

Inset Display Window Filter

Product Specifications

Property	Test	Test Method	Results
Resolution	Viewing backlighted U.S.A.F. resolving power test target with distance of 1.5" (38mm)	F.A.A. E-2481	Will resolve not less than 28 line pairs/mm.
Specular Reflection	Measurement of front surface specular reflection	Reflectometer Spectrophotometer	1.0%
Gloss	Degree of matte surface finish measured with Gardner Laboratory 60° glossmeter	ASTM-D523	54 + 6 gloss units standard
Scratch Resistant	100 gm weight applied to Gardner Laboratory Stylus SC-1620A and drawn across surface	Princeton Scratch Tester	No evidence of scratching
Hardcoat Adhesion	3M Scotchtape 810 pressed and with-drawn from surface	Tape Test	No marks on surface
Thermal	− 60°F (− 55°C) to 200°F (94°C) Continuous	Accelerated Weathering Tester	No change
Flammability	94V-2	U.L.	No change
Chemical Resistance	Staining Agent		Effect
	Alcohols	Agent on surface for 24 hrs., then cleaned	None
	Ball Point		None
	Caustic Soda		None
	Chlorinated Safety Solvent		None
	Coca-Cola		None
	Coffee		None
	Grease Pencil		None
	Lead Pencil		None
	Lipstick		None
	Lysol		None
	Naphtha		None
	Nail Polish		None
	Rubber Cement		None
	Soap and Water		None
	Tea		None
	Stamping Ink		None

Cleaning Agents: Filter surface can be cleaned with Windex, mild detergents, ammonia and water and propanol alcohol.

For colors and applications refer to the following chart:

Standard Inset Display Window Filters

Colors and Applications

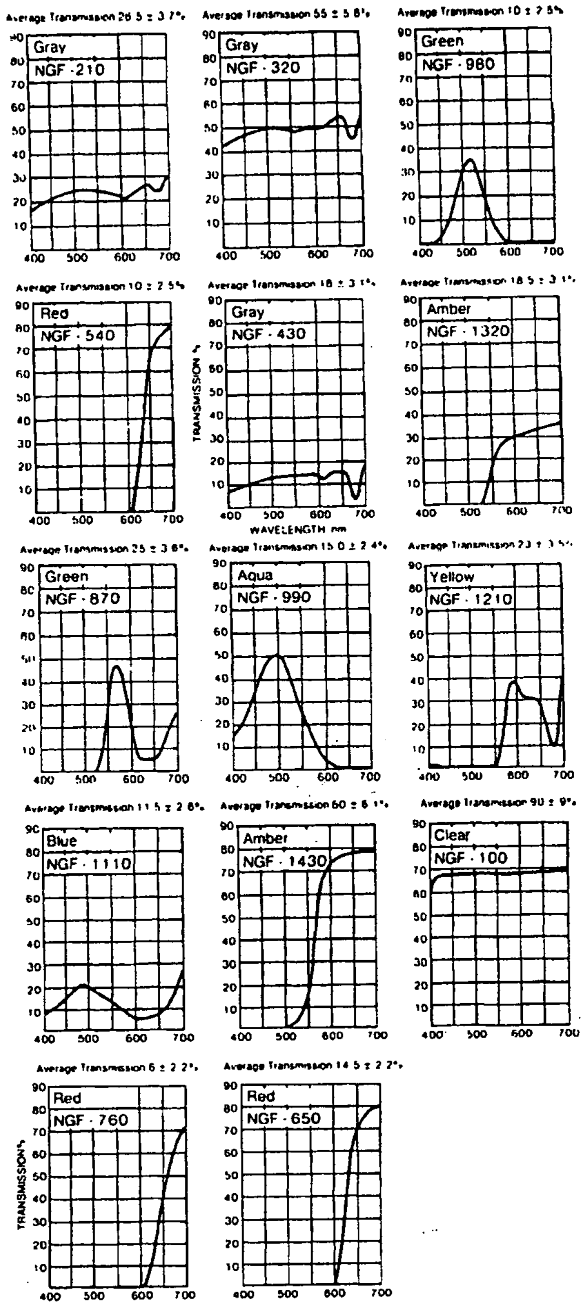
Colors	Material and Thickness	Applications
Clear, NGF-100	Polycarbonate .030", .060"	Excellent with Liquid Crystal
Gray, Medium NGF-210	Polycarbonate .030", .060"	Good with all LED display types. Excellent with white phosphors CRT. Good with vacuum fluorescent, plasma/gas discharge and incandescent
Gray, Very Light NGF-320	Polycarbonate .060"	Excellent with Liquid Crystal
Gray, Very Dark NGF-430	Polycarbonate .030"	Excellent with yellow LED display, vacuum fluorescent and incandescent. Good with plasma/gas discharge
Red, Ruby NGF-540	Polycarbonate .030", .060"	Excellent with red LED display
Red, Scarlet NGF-650	Polycarbonate .030", .060"	Excellent with orange-red LED display and plasma/gas discharge
Red, Dark NGF-760	*Rigid Vinyl .030", .060"	Excellent with incandescent and red LED display
Green, Light NGF-870	*Acrylic .060"	Excellent with green LED displays
Green, Medium NGF-980	*Rigid Vinyl .030"	Excellent with vacuum fluorescent and green phosphors CRT
Aqua NGF-990	Acrylic .060"	Excellent with vacuum fluorescent
Blue NGF-1110	Polycarbonate .030"	Excellent with vacuum fluorescent
Yellow NGF-1210	Acrylic .060"	Excellent with yellow LED display
Amber, Dark NGF-1320	Rigid Vinyl .030"	Excellent with incandescent
Amber, Medium NGF-1430	Polycarbonate .030"	Excellent with plasma/gas discharge

**Thermal Properties and Flammability Ratings are different from those of polycarbonate. Rigid vinyl withstands temperatures between −40°F (−40°C) to 125°F (54°C) with a U.L. flammability rating of 94V-0. Acrylic withstands temperatures between −40°F (−40°C) and 150°F (65°C). Flammability is 94 HB per U.L.*

Display Zones

For standard color filters with spectral and transmission values refer to the following chart:

Spectral Curves
Average Transmission for Standard Materials



15.2 Screen-Printed Window Filters

Sreen-printed window filters provide a cost effective alternative to dyed filters. Screened filters not only require less assembly, they enable the surface of the graphic overlay to consist of a continuous, uninterrupted surface. This ensures that dirt buildup will be kept to a minimum.

15.2.1 Manufacturing Process

In the past, screen-printed window filters have suffered from the uneven appearance of the ink pigment. With the advent of new screen-printing techniques and higher pigment concentrations this criticism is no longer a major concern.

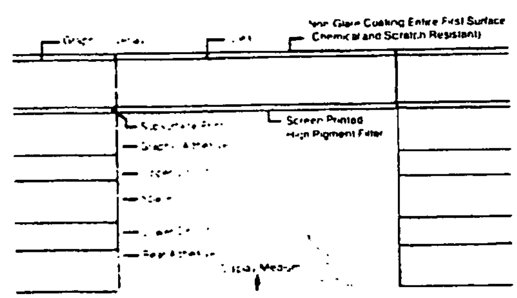
The inner sub-surface of the polyester or polycarbonate graphic overlay is screen printed in the intended window area with high-pigment filter ink. By matching the ink to the spectrophotometric value and transmission curve constant of the electronic display, those light wavelengths mainly emitted by the display are allowed to freely pass through the filter while other wavelengths are blocked. This enhances the apparent brightness and contrast of the display.

Note

Screen-printed spectrophotometric tolerances are less exact than those of dyed filters.

A dark graphic overlay background is advised in order to avoid any bleeding of the window filter ink with the graphic overlay ink.

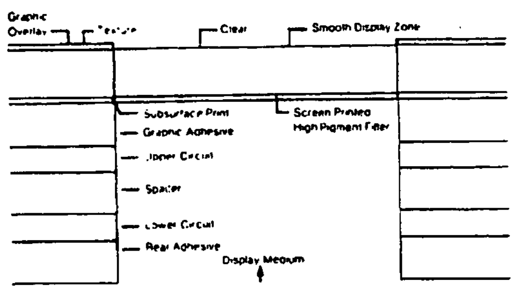
Non-Glare Screen Printed Display Window Filter



Display Zones

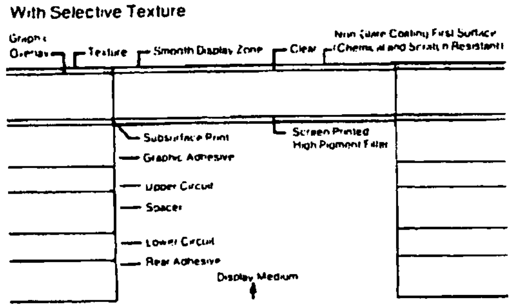
A U.V. photosensitive surface texturing can be applied to the face of the graphic overlay to define keyboard areas while the window filter area remains untextured for maximum clarity.

Screen Printed Display Window Filter with Selective Texture



Finally, a non-glare, chemical and abrasion resistant coating can be applied over the entire exposed surface, enhancing the visual aspect of the display.

Non-Glare Screen Printed Display Window Filter With Selective Texture



15.3 Dyed-Underlaminate Window Filters

Dyed-underlaminate window filters offer the advantages of a continuous first surface graphic and the high-quality spectrophotometric values of dyed filter material.

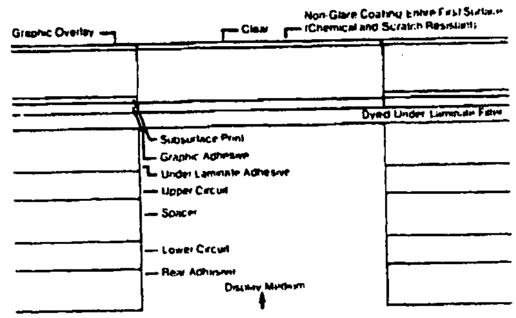
15.3.1 Manufacturing Process

The window display area remains clear of any graphic background printing during the standard sub-surface printing of the graphic overlay. A dyed polycarbonate film that is typically 0.005" thick is then laminated to the subsurface of the overlay with acrylic adhesives.

Finally, the filter and graphic overlay assembly is mounted over the switch layers and the electronic display. This one-piece construction greatly reduces manufacturing time and materials when compared to an inset window filter construction.

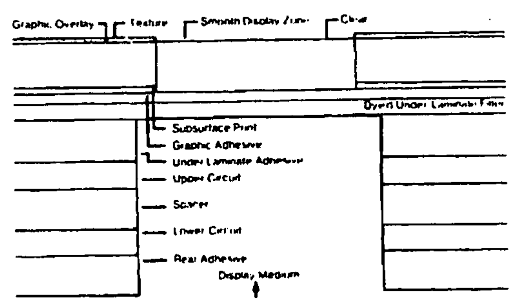
The dyed filter holds the close spectrophotometric values mentioned in Section 15.1.1.

Non-Glare Under Laminate Display Window Filter



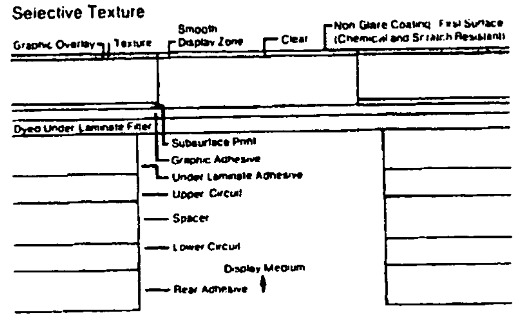
A U.V. photosensitive surface texturing can be applied to the face of the graphic overlay to define keyboard areas while the window filter area remains untextured for maximum clarity.

Under Laminate Display Window Filter with Selective Texture



As with the other filters, a non-glare, chemical and abrasion resistant coating can be applied over the entire exposed surface.

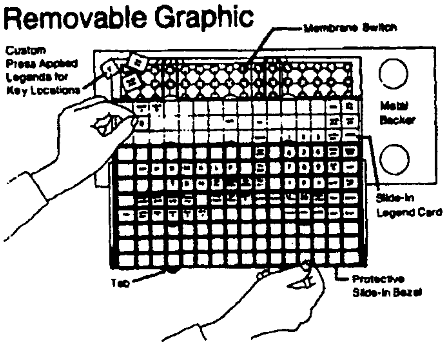
Non-Glare Under Laminate Display Window Filter with Selective Texture



Chapter 16
Removable and Interchangeable Graphics

Removable graphics are defined as a technique that permits the user to remove the entire graphic area of the keyboard. Once removed, the graphic layer can then be replaced by another graphic. This design is particularly useful when the product requires the flexibility of multiple key definitions, such as on a point of sale terminal.

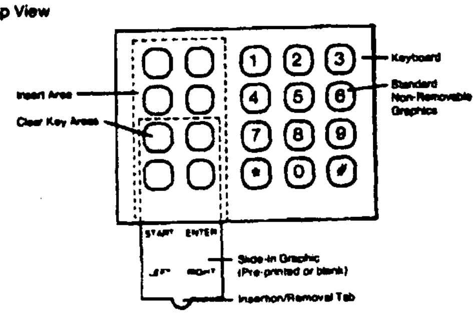
Removable Graphic



Interchangeable graphics resemble removable graphics except that the user can only change predefined sections of the graphic overlay. If, for instance, a keyboard contained a number of basic function keys complemented by several application-specific keys, then it may be desirable to enable the customer to change the graphics relating only to the application-specific keys.

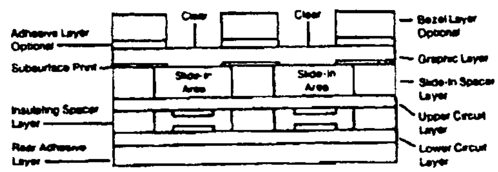
Interchangeable Graphics

Top View



Interchangeable Graphics

Cross-Section



Removable and interchangeable graphics require adequate space between keys to allow for easy overlay replacement. As a general rule, the minimum area needed between keys is .220".

Both membrane and tactile metal dome keyboards can accommodate this feature.

Because this design demands customizing, it is advisable to contact the keyboard manufacturer as early in the specification phase as possible.

Chapter 17
Backlighting

Membrane technology makes use of many forms of backlighting:

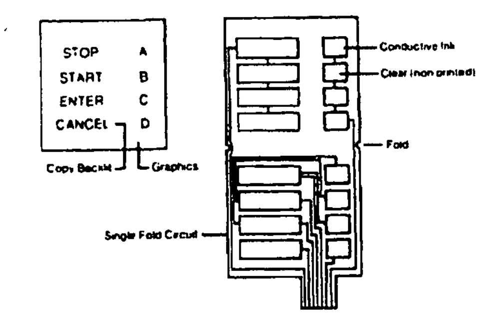
- Non-functional illumination of graphics
- Fully illuminated flat and tactile keys
- Integrated displays that combine illumination with function

When designing a keyboard, you can ensure the alignment of illumination devices by combining switching and illumination functions into a single assembly.

If your application requires backlighting, you should inform the keyboard manufacturer early in the design process.

17.1 Subtractive Circuitry
Subtractive circuitry consists of screen-printing a selective conductive pattern on both the upper and lower circuits. This selective pattern is deposited to areas within the keypad which will not be illuminated from behind. The areas of desired illumination are left clear and non-conductive.

Subtractive Circuitry/Flat



This process can be applied to both flat and tactile membrane products, permitting graphic illumination within the keypad areas.

17.1.1 Design Guidelines
Assuming that the average keypad is .500", the following guidelines apply:

1 The non-conductive clear area must be within a radius of .06-.09" of the center of the switch.

2 The graphic overlay over the non-conductive clear keypad area can be illuminated from behind the keyboard.

3 As much conductive pad area as possible should be included in the design. Additional pad area can be achieved by printing conductive ink in areas surrounding the graphics to be illuminated.

4 When subtractive circuitry is used, encoding is generally limited to x/y matrix and common buss.

5 A conductive routing path to the circuit pad is required. The minimum lead width is typically .020".

17.2 Electroluminescence
Should more than 40% of a keypad require backlighting, thin film electroluminescent panels may be an alternative.

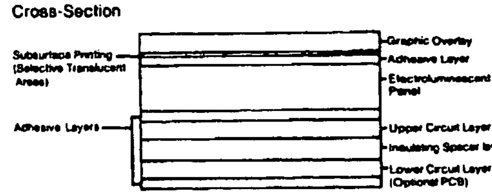
An EL panel consists of a thin phosphorescent polycrystalline material and an aluminum rear electrode. When an electrical current is applied, illumination points appear.

Light out levels are from 15 to 200 foot/lamberts. The light display is currently monochromatic.

EL flexible panels can be manufactured to vary in size.

Electroluminescent Micro-Motion Flat Membrane

Cross-Section



17.3 Incandescent Lamps

Low-voltage incandescent lamps can be used to backlight graphic copy or functional keys.

17.3.1 Manufacture

When intended for backlighting graphic copy, the incandenscent lamp(s) is commonly incorporated into a rigid plastic backer unit, which is a customized product that requires either routing or injection molding. The translucent plastic backer acts as a light pipe, diffusing the illumination over the surface of the plastic. The membrane keyboard is then adhered to this plastic backer.

The graphic overlay and/or circuitry is designed so that illumination projects through the desired areas.

17.3.2 Selectively-Illuminated Copy

Selectively-illuminated copy within individual keypads can be produced by using the subtractive circuitry discussed in Section 17.1.

The keyboard is then bonded to the surface of a plastic light-pipe backer as described earlier in Section 17.3.1.

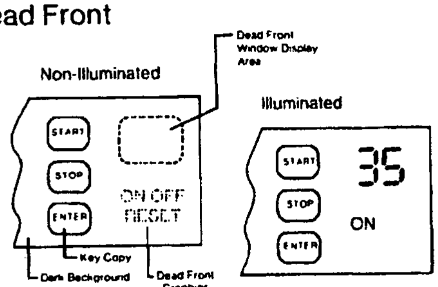
17.4 Dead Front

The term "dead front" refers to a process in which areas of illumination in a graphic display are rendered undetectable until they are illuminated. This can include such things as L.E.D.s, display devices, incandescent lamps, or backlit graphics.

This effect is achieved by applying a transparent black or darkly colored ink over the area to be concealed, using a screen-printing process. The surrounding area of the keyboard should be as dark as the ink to be effective.

In areas such as display zones, a second transparent color can be added behind the dead front to enhance the brightness of the display. Chapter 15 discusses display zones.

Dead Front



Chapter 18
Electronic Component Assembly

Electronic components can often be incorporated into membrane keyboard designs. This approach offers many inherent advantages:

- Designing components into the switch assembly ensures alignment of devices such as L.E.D.s and seven segment displays with the graphic overlay portion of the keyboard.
- Assembling components at the keyboard level is more economical than adding electronics on a second PCB.
- Receiving a module, that is a fully tested and functional keyboard with electrical components, eliminates the need for individual component testing by the assembler.

The design of a keyboard module should also consider maintenance. In particular, it must be easy for individual components to be removed and serviced as required.

18.1 Light Emitting Diodes

Light emitting diodes, or L.E.D.s, verify data entry or process operation of many keyboards. There are three commonly used L.E.D.s:

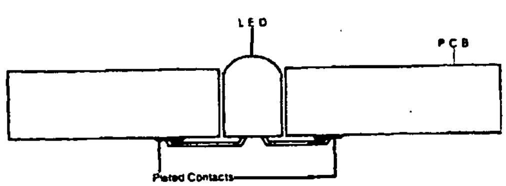
1 Lamp type
2 Bar display
3 Seven segment display

This section discusses the lamp type, which is frequently included in keyboard construction.

18.1.1 Rear Mounting

Except for transparent technology keyboards, the lower switch layer consists of either a flexible membrane or rigid printed circuit board. With rear assembly of L.E.D.s, a slight protrusion of the L.E.D. from the rear surface is unavoidable, regardless of the lower switch type.

Rear Surface Mounted L.E.D. on Printed Circuit Board



A solder connection positions the L.E.D. at the rear of the PCB. This connection can take two forms:

1 A direct solder joint to the PCB
2 A receptacle socket soldered to the PCB

The second alternative has the advantage that the L.E.D. can be easily inserted and removed since it simply inserts into the socket.

When a flexible membrane lower circuit is used, the L.E.D. assembly requires solderless conductive epoxies and adhesives. Field replacements of L.E.D.s that have been assembled in such a manner are difficult. Consequently, the keyboard manufacturer is usually responsible for such replacements. (Refer to Section 18.4 on conductive epoxies.)

The following L.E.D.s have a lamp profile that is well-suited for rear assembly:

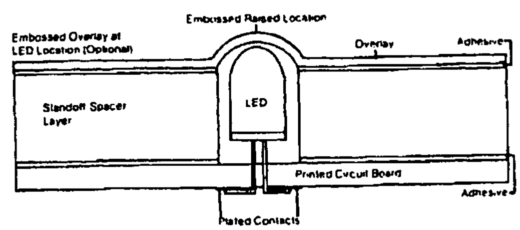
- Hewlett Packard HLMP-6300-RED
- Hewlett Packard HLMP-6400-YELLOW
- Hewlett Packard HLMP-6500-GREEN

18.1.2 Top Mounting

Lamp type L.E.D.s can also be integrated into the keyboard assembly. Both rigid printed circuit boards and flexible design circuits can be used with this approach.

Top mounting requires the addition of a spacer or standoff layer above the upper circuit. This layer compensates for the lamp profile and ensures that the graphic overlay maintains a uniform first surface.

Top Surface Mounted L.E.D. on Printed Circuit Board



The standoff layer requires either routing or injection molding.

The actual attachment of the L.E.D.s involves the same procedure as rear mounting.

18.2 Numeric, Character, and Light-Emitting Displays
Displays help verify, select, and monitor functions controlled by the keyboard. There are three commonly-used displays:

1 Seven segment L.E.D.s
2 L.E.D. light bars
3 Liquid crystal (L.C.D.)

Display components require a high density of output lines and, consequently, a rigid PCB is recommended as the lower circuit.

Like L.E.D.s, display components can be assembled on either the top or rear side of the lower circuit layer. This selection depends on the profile of the specific component and the amount of available space behind the keyboard.

18.2.1 Rear Assembly
Display components are typically mounted on a secondary PCB, referred to as a daughter board. This daughter board interfaces to the lower circuit using either a simple mechanical connection or an electrical solder connection. This choice depends on the density of both the display and keyboard outputs.

The design of such a keyboard should ensure that individual components can be easily removed and maintained.

18.2.2 Surface Assembly
Top surface mounting of displays offers the advantage of creating a protective package that minimizes potential damage in shipment and handling.

The display components are soldered to the top side of the lower circuit layer. A spacer or standoff is then added to the lower circuit. This layer compensates for the profile of the components and ensures that the graphic overlay maintains a uniform surface.

The standoff layer requires either routing or injection molding.

When designing a keyboard that uses top surface mounting, the electrical density of both the switch functions and the display outputs should be carefully reviewed. Multi-layered PCBs can help to offset electrical density.

18.3 Other Components
Components such as mechanical switches, micro-processors, and integrated circuitry can be incorporated into membrane keyboard designs.

Assembly of these and other components can utilize either the front or rear mounting techniques described in the previous sections.

The use of flexible circuitry and multi-layered PCBs greatly enhances the design possibilities for component assembly.

Developing a module system requires considerable interaction between the customer and keyboard manufacturer. Consequently, the keyboard manufacturer should be involved at the earliest possible time in the design procedure.

18.4 Conductive Adhesives
Conductive adhesives enables L.E.D.s to be terminated to a flexible circuit. This technique is advantageous when mounting space requirements prevent a thicker lower PCB circuit from being used.

Conductive adhesives consists of a silver-based adhesive binder.

Chapter 19
Keyboard Mounting

When designing a keyboard, an understanding of various final mounting techniques can help you address the following fundamental concerns:

- Sealing the keyboard
- Static discharge protection
- Cleaning the keyboard
- Maintaining the keyboard

As a general rule, the benefits of a well-designed interface between the keyboard and its housing far outweigh cost considerations.

19.1 Adhesives
Many keyboard assemblies provide an acrylic adhesive as the rear mounting surface. This adhesive allows the customer to position the keyboard on the equipment during the final assembly.

Adhering the keyboard involves removal of a backer layer, which exposes the adhesive substance. In addition, positioning or locator holes can be supplied to ensure that the keyboard is properly positioned.

Once adhered to the equipment, the keyboard cannot generally be repositioned. There is, however, a 72-hour cure period required for the adhesive to initially bond. For this reason, "burn in" and environmental testing should not occur before the end of this time.

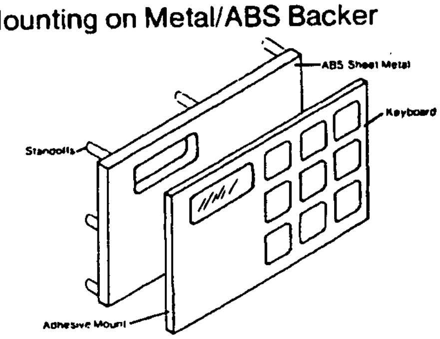
Section 5.1 contains a detailed listing of adhesives and their properties.

Note that adhesive mounting requires that the housing includes a rigid mounting surface which must be thoroughly cleaned before assembly.

19.2 Backer Types
A substrate can be adhered to the rear side of a keyboard to provide a rigid single unit assembly

Acrylic adhesive usually provides the bonding substance to adhere the rigid backer substrate to the keyboard. The rigid backer material typically consists of aluminum, ABS or Lexan (polycarbonate) plastics. Common thicknesses are .032", .062", .092" and 0.125"

Mounting on Metal/ABS Backer



The backer-mounted keyboard is affixed to the equipment by either heat stakes, standoffs, or studs. These can be incorporated onto the backer, or provisions can be made for them to be part of the equipment itself.

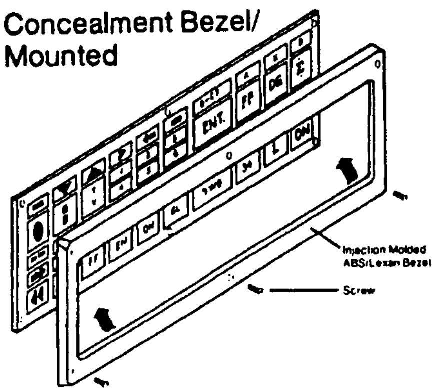
When suppression of internal component-generated RFI or EMI is important, an aluminum backer should be used. The aluminum surface supplies the necessary shielding or blockage of RFI or EMI. For optimum performance, the aluminum shield should be grounded directly to the equipment.

Backer mounted keyboards can be more easily repositioned than adhesive backed products. In many applications, the backer mounted keyboard is directly assembled to an internal PCB. This approach enables the final positioning and assembly of the keyboard to occur from the backside of the coverplate.

Positioning the keyboard in an undersized opening in the front panel protects the edges of the keyboard from the user and greatly increases E.S.D. protection.

19.3 Front Mounting Bezel
In keyboard designs utilizing adhesive mounting only, a front mounted perimeter bezel increases the protection and appearance of the keyboard.

Edge Concealment Bezel/
Front Mounted



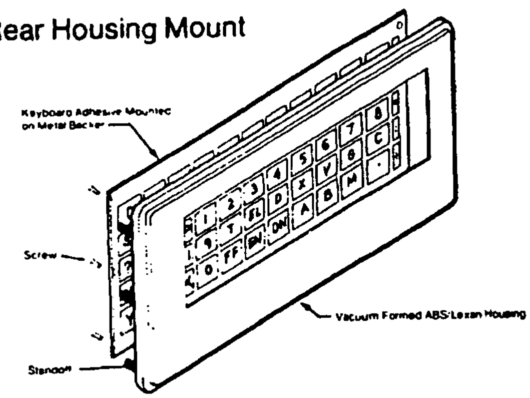
An adhesive on the rear of the keyboard is used to mount the keyboard on the equipment. Once mounted, a separate perimeter bezel with corresponding countersunk holes is then placed over the keyboard. The bezel is held in place by threaded screws which extend through the bezel and keyboard perimeter and lock into the equipment housing. Rubber gaskets can also be used in conjunction with the bezel for increased seal integrity.

The danger of electro-static discharge decreases when a bezel is added because it effectively conceals the edge of the keyboard, reducing the possibility of E.S.D. flashover and environmental contamination.

The perimeter bezel used in this design is typically injection molded, although small volumes are possible with vacuum form or routing techniques.

19.4 Rear Mounting
Keyboard designs that utilize the rigid backer mounting technique can increase their protection and appearance by incorporating rear mounting.

Rear Housing Mount



In this approach, the keyboard is mounted to the rear side of the front panel with studs and/or a standoff. A rubber gasket can be added for increased sealability from environmental contamination. The danger of electro-static discharge also decreases because the edge of the keyboard is effectively concealed, reducing the possibility of E.S.D. flashover.

The front panel cutout is smaller than the actual keyboard assembly. The user operates the keyboard through this opening in the panel.

Chapter 20
Forming/Cutting Tools

20.1 Forming Tactile Membrane

When choosing a tactile membrane design, a match mold tool set is required to form the domes. The tooling necessary is a machined bottom plate and matching molded top plate.

Tactile membrane keyboards are typically manufactured in what is termed a one up mode. This does not mean that each dome is formed individually but that each keyboard with all its associated domes is formed at one time.

Tolerance of the formed dome location is ± .005".

20.2 Embossing

Any type of graphic embossing requires a match mold tool set. The type of tooling required to emboss is similar to that needed for dome forming. All keyboards using a tactile membrane or tactile metal dome/PCB switch without an actuator layer require embossing to raise the graphic overlay keypads.

Embossing tools can sometimes be achieved in what is known as multi up format. The decision on using single or multi up embossing tooling is dictated by the size of the part and the quantity of the order.

20.3 Steel Rule Die

The most commonly used cutting tool for flexible layers is known as a steel rule die. These dies are manufactured using a gas laser beam which cuts a thin slot in a piece of 3/4" hard maple die board. Formed stainless steel blades are then inserted into this slot. Each sublayer of the keyboard configuration has its own specific steel rule die which match a precisely drawn blueprint for that particular layer.

A simple flat membrane switch may have as few as four steel rule dies while a more complex keyboard could have 8–10 dies. The life of a steel rule die is between five and seven thousand cutting impressions. Since size of the part and quantity ordered dictate singular or multi up tooling, a steel rule die could produce as few as 5,000 parts in a one up mode to as many as 70,000 parts in a ten up mode.

When higher quantities exist, multi sets of steel rule dies should be purchased to produce higher volumes.

Overall steel rule die tolerances are ±.010".

20.4 Hard Tooling

Hard tooling consists of a male and female machined steel tool set. When either volume or tolerance levels exceed those normally achieved with steel rule dies, hard tooling is suggested. Hard tooling, although more costly, can produce quantities in excess of 1 million units and a consistent tolerance level of ±.003". Quite often hard tooling will be used on specific sublayers of a keyboard, typicallly the circuit layers which include the flextail.

Chapter 21
Environmental Tests

21.1 Thermal Shock
Tested under Mil. Std. 202, Method 107D, Condition A.

This test determines the resistance of a part to exposure at extremes of high and low temperature, such as might occur when equipment or parts are transferred to or from heated shelters in Arctic areas. It also tests the effect of the shock of alternate exposures to these extremes.

The part is tested in a two hour dwell time between a low temperature of −55°C and a high temperature of 85°C. The tested part should not show change in operating characteristics or physical damage caused by the thermal shock, such as changes in electrical characteristics or mechanical displacement of dimensions causing delamination of insulating materials or finishes.

21.2 Humidity
Tested under Mil. Std. 202, Method 103B, Condition A.

This test evaluates the influence of absorption and diffusion of moisture vapor on component materials.

This accelerated environmental test involves the continuous exposure of the assembly to a 95% relative humidity at 40°C for a period of ten days.

The insulating materials in the assembly should not absorb moisture, which can cause swelling or harm any important mechanical characteristic or degrade any electrical property.

21.3 Moisture Resistance
Mil. Std. 202, Method 106E.

Similar to the humidity test, the moisture resistance test evaluates the resistance of component assembly parts to high humidity and heat conditions that typify tropical environments.

The test differs from Method 103 by providing alternate periods of condensation and drying which determines whether the circuitry develops any corrosion. The test should not detect any deterioration of electrical characteristics nor any discernable differentiation in resistance.

21.4 Salt Spray
Tested under Mil. Std 202, Method 101D, Condition A.

The salt spray test subjects the circuit component parts to a fine mist from a 5% salt solution creating a marine environment of ocean water atmosphere. The test determines resistance to salt spray corrosion and evaluates the uniformity, thickness, and degree of porosity of protective coatings on circuitry as well as the relative life and behavior of different conductive materials in an exposed seacoast or marine location.

The test should reveal no change in electrical characteristics (minor change in resistance if circuit exposed to the open atmosphere).

21.5 Solvent Resistance
Mil. Std. 202, Method 215A

This test verifies that component parts (including circuitry and graphics) do not become illegible or discolored when subjected to solvents normally used to clean fingerprints and other contaminants.

After immersing the component part in a liquid detergent solution and brushing it, there should be no deterioration of the material or finish, nor should the solvents cause any mechanical or electrical damage to the assembly.

21.6 Shock
Mil. Std. 202, Method 213B, Condition A.

This test exposes the circuit component subassembly to a shock that can be expected as a result of rough handling, transportation, or military operations.

The assemblies are exposed to a peak value of 50 g's over a normal duration of 11 milliseconds.

21.7 Vibration
Tested under Mil. Std. 202, Method 201.

This test determines the effects on component parts of vibration within the predominant frequency ranges and magnitudes that may be encountered during field service.

The result of the vibration should not cause a loosening of the subassembly parts or any motion between the parts that could cause a physical distortion resulting in any fatigue or failure of the switches.

21.8 Fungus
Tested under Mil. Std. 810C, Method 508.

This test creates a metabolic process causing a micro-organism fungus to grow. A humid, warm atmosphere with inorganic salts present is favorable to such growth.

The resulting micro-organisms can produce a living bridge across circuitry which can result in electrical failure and potential corrosion.

No electrical failures should result after a 28 day incubation period.

21.9 Dust or Fine Sand
Tested under Mil. Std. 810, Method 510.

The dust test ascertains the ability of an assembled keyboard to resist the effects of a dry dust or a fine sand atmosphere. The penetration of dust can form an electrical conductive bridge resulting in shorts and can also act as a nucleus for the collection of water vapor and hence serve as a source of possible corrosion and equipment malfunction.

The test should result in no discernable penetration of the dust into cracks or crevices of the keyboard and should not effect electrical performance.

21.10 Migration
Tested under Mil. Std. 202, Method 106.

The test for silver migration is the same as that for moisture resistance. The purpose is to determine whether condensation on the silver surface will cause any migration of silver particles.

The test should result in no shorting out or arcing.

21.11 Sulphur
This test creates a sulfur dioxide environment in order to determine whether there is any change in or loss of resistance.

After 10 days in 80% relative humidity at 60°C there should be no loss of resistance.

21.12 Fold
This test exposes a flexible circuit to the MIT fold endurance test.

After 200 cylces at 270' there should be an inconsequential increase in resistance.

21.13 Adhesion
Adhesion of conductive ink on film is performed by a tape pull test by using 3M #810 tape. This test should also be performed after thermal shock and humidity cyles.

21.14 Abrasion
The hardness of the silver and resistance to abrasion or scratching should be tested using a Hoffman scratch-hardness tester S6-1610M or by Method ASTM D3363-74 with a pencil border. The tests should reveal no marring after moderate pressure.

Glossary

Actuator—A formed or molded protrusion to make contact with the center of a switch location improving tactile feedback.

Analog—An encoding output that electronically identifies switch location by resistive values.

Bezel—A molded, routed, or die cut plastic frame mounted on the face or perimeter of a keyboard.

Common Buss—An encoding output that consists of one circuit lead for all switch locations or group of switches.

Contact Bounce—The time required for an electrical contact to be stable after closure.

Contact Rating—The maximum volts, amps, and watts electrically passed through a switch.

Curing—A process of drying conductive ink for maximum reliability.

Custom Keyboard—A custom design requiring special tooling.

Die Cut—To make an opening by means of a sharp edged steel knife set in a holding tool.

Emboss—A raised configuration accomplished with additional tooling.

EMI—Electro magnetic interference—electro magnetic force generally produced by electrical motors in operation.

Encoding—The assignment of electrical impulses to specific key locations.

ESD—electro-static discharge—static electricity accumulation on one surface area and discharged to another surface when they come near each other.

Flexible Keyboard—A keyboard designed with a non-rigid lower circuit.

Flexible Tail—The termination exit which is an integral part of a flexible circuit in all flexible membrane keyboards.

Folded Circuit—A low cost circuit construction technique where one flexible circuit is folded to form an upper and lower circuit.

Heat Stake—A bonding technique consisting of heating formed plastic pins to hold a keyboard assembly.

Interdigitated Finger Pad—A contact pad configuration that consists of two or three inputs that appear on the same contact surface.

Living Hinge Key—A key connected to a plastic hinge.

Matrix—An encoding method to arrange switch groups in particular rows and columns.

Migration—The leaching out of particles in a conductor when exposed to a high humidity and moisture environment.

Resistance—The contact ohms resistance of a closed switch, or circuit contact.

RFI—Radio frequency interference—high frequency radio waves.

Rigid Membrane—A membrane keyboard with a rigid lower PCB circuit.

Selective Texture—A surface coating to texture selective areas on a graphic overlay.

Shielding—A method to protect the keyboard from interference or static discharge

Shorting Pad—Conductive contacts printed on the upper layer of a switch.

Spacer—An insulating non-conductive substrate with opening at switch locations to separate the upper and lower circuit layers.

Tactile Feel—The snap action feel of domed keyboards with graphics or keytops, and the full stroke of full travel membrane keyboard.

Termination—The means to electrically connect the contact switches of a keyboard.

Travel—The downward movement of a key or the distance between the upper and lower contact.

Ultra-Sonic Weld—A bonding method of switch layers using high frequency sound waves.

Venting—An air channel cut in a spacer layer connecting groups of switch locations for air pressure equalization during switch closure.

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